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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 55

GEOLOGY AND WATER RESOURCES OF A PORTION OF YAKIMA COUNTY, WASH.—Smith

WASHINGTON
GOVERNMENT PRINTING OFFICE
1901

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES

OF

A PORTION OF YAKIMA COUNTY, WASH.

BY

GEORGE OTIS SMITH

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, April 1, 1901.

SIR: I have the honor to transmit herewith a paper entitled Geology and Water Resources of a Portion of Yakima County, Wash., by George Otis Smith, and to recommend that it be published in the series of pamphlets on water supply and irrigation. Mr. Smith has, in connection with his studies of the geology of the vicinity of North Yakima and Ellensburg, familiarized himself with the geology of this region, and in the above-described paper has given special attention to the artesian development of the Yakima Valley. In Bulletin No. 108, by Prof. I. C. Russell, published in 1893, there will be found a description of the geologic structure adjacent to the drainage basin of Yakima River, giving special attention to the occurrence of artesian wells. Professor Russell continued his studies in 1896, and the results were published in Water-Supply Paper No. 4, entitled A Reconnoissance in Southeastern Washington. Mr. Smith, after a more detailed investigation, has been able to give additional facts regarding the conditions of this section.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHAS. D. WALCOTT,
Director United States Geological Survey.

GENERAL VIEW OF ATANUM-MOXEE VALLEY.

GEOLOGY AND WATER RESOURCES OF A PORTION OF YAKIMA COUNTY, WASH.

By George Otis Smith.

INTRODUCTORY.

The region discussed in this report is in central Washington. It is mapped in Pl. II and in fig. 1. The area shown in Pl. II includes more than 750 square miles, but the district to which special attention is given comprises about 50 square miles in the vicinity of the city of

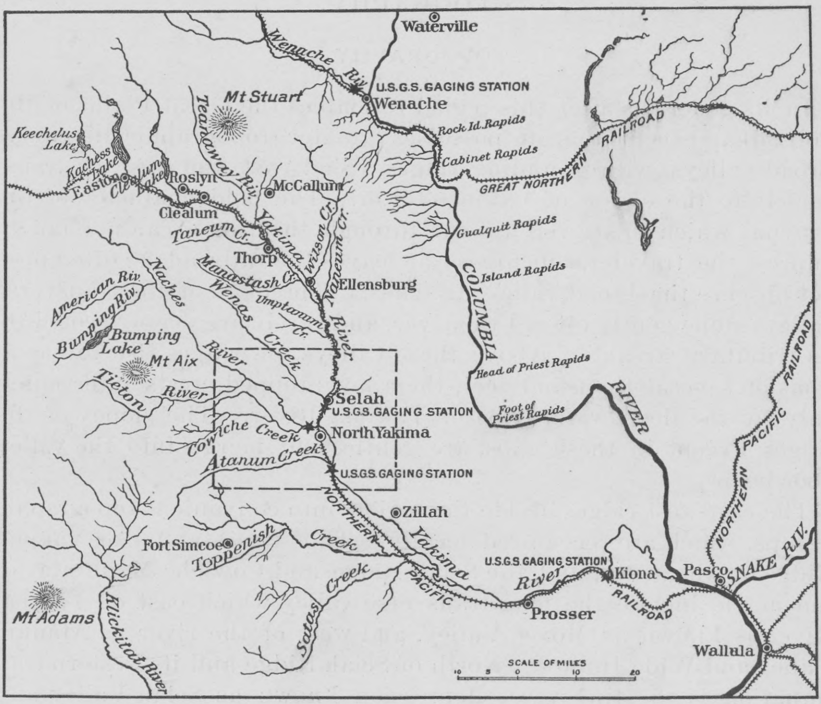

FIG. 1.—Map of central Washington.

North Yakima. The western half of the area is included in the Ellensburg quadrangle. It has been surveyed both topographically and geologically by parties from the United States Geological Survey, and a geologic atlas of the district is now in course of preparation.

The field work upon which this report is based was carried on during July and August, 1900. A reconnaissance of the same area was made eight years ago by Prof. I. C. Russell.[1] At that time, however, only a beginning had been made in the development of the artesian resources of the district, and, in addition, Professor Russell's opportunities for observation were limited by the hurried character of his reconnaissance. In the preparation of this paper the writer has had before him the report of Professor Russell's reconnaissance, and the modifications of Professor Russell's conclusions which may be proposed herein are based upon additional evidence which has been collected since that report was written.

The writer wishes to express his indebtedness to Mr. F. H. Newell, hydrographer in charge, also to Mr. Cyrus C. Babb, of the Division of Hydrography, for suggestions made in the course of the preparation of this report. In the discussion of surface waters extracts have been freely made from the reports of Mr. Newell and Mr. Babb, and some entire paragraphs have been written by the latter gentleman.

GEOGRAPHY.

TOPOGRAPHY.

In its general aspect this region resembles the Great Plains of the Columbia, except that it possesses greater topographic diversity. Broad valleys, with bounding ridges, trend east and west, or transversely to the course of Yakima River. The bold character of the canyons which this river has cut through the ridges can not fail to impress the traveler, but unless he leaves the railroad he often does not observe the broad valley stretches. The floors of the transverse valleys slope gently toward the river, and rarely are deeply scored by its tributary streams. Above these valleys the ridges rise to elevations of several thousand feet, their level-topped crests interrupted only by the deep water-gaps of Yakima River. The slopes of the ridges, except in these gaps, are gentle, and merge into the valley floor below.

The east-west ridges divide the region into convenient topographic groups, which are recognized locally. Thus the Atanum or Yakima Ridge on the south, and the Selah Ridge and Cowiche Mountain on the north, inclose the long transverse valley which east of Yakima River is known as Moxee Valley, and west of the river as Atanum Valley and Wide Hollow. North of Selah Ridge and its western continuation is the transverse depression known as Selah Valley and Wenas Valley, while south of Atanum Ridge is the broad valley known as Reservation Valley, which is in large part included within the Yakima Indian Reservation. These subdivisions of the area are geologic as well as topographic, and they will be mentioned further on.

[1] See A geological reconnoissance in central Washington, by I. C. Russell: Bull. U. S. Geol. Survey No. 108, 1893.

CLIMATE.

This region has the arid climate of the Columbia Plains. In the vicinity of North Yakima the annual rainfall averages slightly more than 8 inches, and in the eastern part of the area the precipitation is doubtless even less; but the western and higher portions share in part the climatic influence of the Cascade Range, and there the annual precipitation in the form of rain and snow is considerably greater. As an illustration of this increase, the records kept at Clealum and Ellensburg, both situated in the upper Yakima Valley, may be cited. At the former place, which is 25 miles farther up the valley, the annual precipitation is more than three times that at Ellensburg, while the latter place has a rainfall exceeding that at North Yakima, lower in the same valley. If records were available a similar increase could undoubtedly be shown in the upper portions of Atanum, Cowiche, and Wenas valleys.

The summers are hot and dry, and with the high percentage of bright, clear days are very favorable to agriculture. In the lower valleys the winters are short, and very cold weather is uncommon. The mean annual temperature in the vicinity of North Yakima is about 50° F. The record kept in the year 1895 in Moxee Valley gives the mean as 49.7° F.[1] An excellent index of the varied climate of the region is afforded by the native vegetation. Along the rivers and streams only a few trees are found, the cottonwood being abundant on the east bank of the Yakima near North Yakima, but the rest of the lower valleys, and even the ridges in the central and western portions of the area described, are treeless and of desolate appearance. Sagebrush and associated desert shrubs grow wherever the land is in its primeval state, and the nutritious bunch grass is plentiful on the ridges, except where excessive grazing has destroyed it. In the western quarter of the area mapped the yellow pine appears first in scattered single trees, and then in open groves which add much to the beauty of the scenery as one traverses the higher ridges.

SOIL.

Analyses of soil from Atanum and Wenas valleys[2] show that it is rich in potash, magnesia, lime, and phosphoric and sulphuric acids, constituents which are essential to plant life. The fine texture of the soil is a characteristic doubtless even more important than its chemical composition, for it not only facilitates cultivation, but renders soluble and available a greater percentage of the mineral matter. The aridity of the climate also doubtless has had a beneficial effect, in that the soil has not lost its most valuable constituent by the leaching of subsurface waters.

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[1] First Ann. Rept. Bureau of Statistics, Agriculture and Immigration of State of Washington, 1896, p. 24.

[2] Op. cit., p. 26.

In this connection it may be well to sound a word of warning against the waste of water. Excessive irrigation has already injured certain portions of the lower valleys in this county. Not only does the constant presence of water result in leaching out some of the more soluble of the valuable soil elements, but in the lower levels the action of this water is to bring to the surface certain salts that are injurious to vegetation. Such waste of water in irrigation is thus a double evil. In an irrigation district the good of the community should constantly be considered, and it is the duty of the individual to think of the future as well as the present productiveness of the soil.

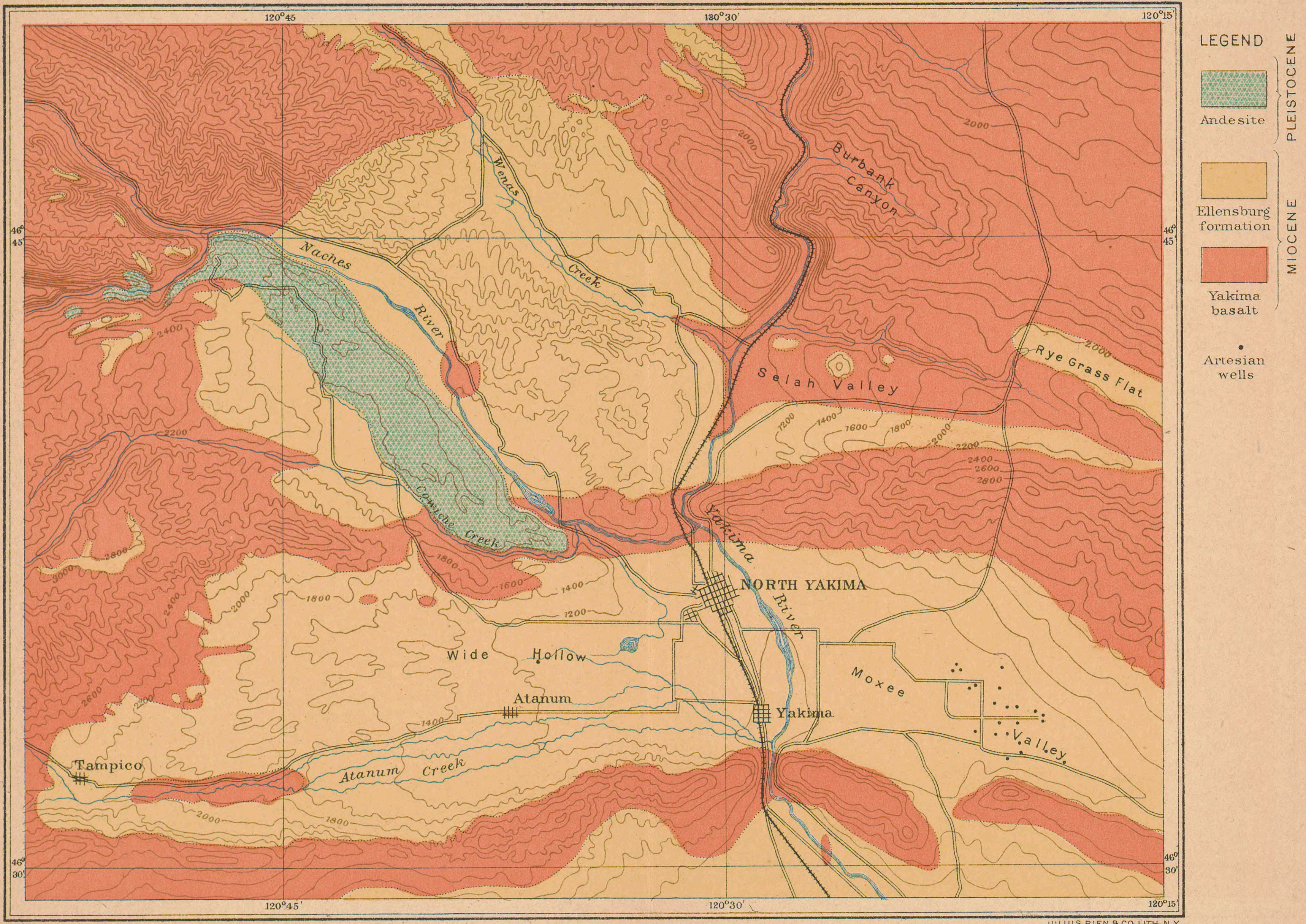
AGRICULTURE.

Yakima County is preeminently an agricultural region. The valleys along Yakima River are within easy reach of the Northern Pacific Railway, which gives them ready communication with Puget Sound. The rapid growth of the trans-Pacific trade is encouraging, and can not fail to benefit the agricultural industry. The Puget Sound cities and Roslyn, a coal-mining town farther up the valley, already are important markets for the products of the Yakima region, and as the mining industry of the Cascades develops additional markets will be afforded.

These valleys are also situated close to the mountainous regions which furnish summer grazing for large herds of cattle and bands of sheep. Grazing in these mountains has often been destructive, but now, under the conservative management of the Secretary of the Interior, it is judiciously regulated. The permanence of these mountain pastures is important to the agricultural industries of the valley, for the cattle and sheep constitute a home market for much of the hay raised there, since winter feeding is necessary.

The crops that are cultivated in this district are many and varied. In the irrigated portion hay is raised which commands a higher price in the Puget Sound markets than that from any other locality. Alfalfa, clover, and timothy are the forage plants commonly grown. Of the cereals, wheat and oats are the most important. Potatoes, sweet corn, and other garden vegetables grow well in the Yakima valleys, and are readily marketed in the Sound cities. Of orchard fruits, apples, peaches, prunes, pears, cherries, and apricots grow to the highest perfection, and the fruit industry may be considered only partially developed, although its success is assured. All of the small fruits grow equally well. This region has also long been famous for the excellent quality of its hops, which crop continues to be an important one. Sorghum is raised to some extent, and as the agricultural possibilities are gradually developed, doubtless the culture of many other crops will be found to be profitable.

At a few localities dry farming has been attempted, but with little success. Wheat and barley are the crops raised where irrigation is



Topography by A.E. Murlin and Northern Transcontinental Survey.

JULIUS BIEN & CO. LITH. N.Y.

GEOLOGICAL MAP OF THE VICINITY OF NORTH YAKIMA, WASHINGTON

BY

GEORGE OTIS SMITH

Scale

0 1 2 3 4 5 6 7 8 MILES

1900.

impossible. It seems probable that with careful selection of northern slopes on ridges where the winter precipitation is considerable and the soil is fine and well fitted to retain the moisture, success may be had in raising these crops. The experience of Mr. John Cleman in raising winter wheat on the north side of Umptanum Ridge is instructive in this connection, for it has proved that that crop can be grown there successfully and profitably.

GEOLOGY.

GENERAL FEATURES.

The basin of Yakima River described here forms an intermediate zone between the Columbia Plains on the east and the Cascade Mountains on the west, and geologically it possesses many features of each. The geologic formations are chiefly those of the Columbia Basin, but the structure is more nearly related to that of the Cascade Range. The rock formations are folded into arches and troughs, but the structure is simple and readily understood by even the railway traveler passing up Yakima River.

The rock seen everywhere along this river is the black basalt, but in certain valleys on the flanks of the ridges white sandstone is visible. These two formations, with the andesite which occurs locally and the alluvium of the valleys, will be described more fully on the following pages.

FORMATIONS.

YAKIMA BASALT.

This formation includes the great series of lavas poured out over this region in late Tertiary time—flood after flood of molten rock, which covered the vast area between what is now the crest of the Cascade Mountains on the west and the mountains of Idaho on the east, and between the mountains of northeastern Washington on the north and the Blue Mountains of Oregon on the south.[1] Solidified tree trunks found at a number of localities show conclusively that considerable intervals separated the lava eruptions. The number of successive flows undoubtedly varies in different parts of the area. In Snake River Canyon, where 3,000 feet of lava is exposed, Russell counted eight distinct lava sheets.[2] Ten or more separate flows can be counted in the canyon of Yakima River, and individual flows be traced great distances. The depth to which the basalt accumulated

[1] The names Columbia lava and Columbia River lava have been used by Prof. I. C. Russell in describing the extensive lava series of the Columbia River Basin. Under these terms are included basalts of both Eocene and Miocene age (Twentieth Ann. Rept. U. S. Geol. Survey, Pt. II, p. 129), also hypersthene-andesite, which is of post-Tertiary age (Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4, p. 43). In the detailed mapping of the Yakima area, which is a part of the Columbia River Basin, it has been found inadvisable to use this general formation name, because the lavas of different ages must necessarily be separated, and therefore the term Yakima basalt is used for that of the Miocene period.

[2] Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4, p. 48.

can be stated only approximately. In the Snake River region the maximum thickness is estimated to be in excess of 5,000 feet.[1] In the Yakima region more than 2,500 feet is exposed in vertical section in the canyon of Yakima River, and as the section includes neither the top nor the base of the lava series, the real thickness may possibly approximate that along Snake River. To the west and north the basalt series is plainly thinner where it overlaps the older rocks.

Examination of the lower contact of the Yakima basalt shows that at the time of the earlier eruptions the topography was extremely rugged. The depressions were, however, gradually filled with molten rock and the inequalities obliterated, just as the waters of a lake conceal the uneven bottom, so that at the cessation of the eruptions the lava series had the aspect of a monotonous waste, rough in detail but generally level over a vast extent of country.

As seen in Yakima County, the basalt is a black rock, compact and heavy. On the weathered surface it is often of a brownish color, but wherever exposed it is dark, and the appearance of the ridges is dull and somber, unrelieved by even the desert vegetation. In a few places, where the residual soil can be found unmixed with alluvial or other foreign matter, it is of a bright-red color.

The most noticeable feature of the basalt rock is the columnar parting by which the black sheets of lava are broken up into long colonnades. In some localities these columns are prismatic, with sharp edges and even sides, the prisms being often so regular as to suggest the work of human hands. This parting is the result of contraction or shrinkage of the solidified lava as the rock mass gradually cooled. The presence of these joint cracks is important, because they afford passages for water in a rock relatively impervious. It therefore is interesting to note the presence or absence of the jointing of the basalt where it is exposed, and such observations have their bearing upon the discussion of the course of the underground waters.

The basalt of certain flows has extremely rough and scoriaceous surfaces, due to small cellular cavities which were formed by the steam in the molten rock and which greatly alter its appearance. These varieties, which tell so graphically the story of the lava eruptions, are less common than the compact basalt. Fine and coarse tuffs, or so-called ash beds, are found at a few horizons in the basalt series, but such beds are insignificant when compared with the thicker and more common lava sheets. In a few instances, however, these fragmental deposits are of importance, one noteworthy locality being Bald Mountain, at the head of Wenas Creek. There the beds of yellow tuff, full of angular fragments of glassy basalt, aggregate

[1] Op. cit., p. 42.

several hundred feet in thickness, and are very noticeable on the northeastern slope of the peak.

ELLENSBURG FORMATION.

Lying directly upon the basalt is the sedimentary series to which the name Ellensburg formation has been given. This series includes partially consolidated sandstones, shales, and conglomerates, with unconsolidated sands and gravels, and represents sediments deposited upon the basalt immediately after the cessation of the eruptions. In the larger part of the North Yakima area, however, some of these sediments were laid down before the eruption of the last flow of the basaltic lava, for at a number of localities 20 to 100 feet of the white Ellensburg can be seen capped by a similar thickness of black lava with the characteristic basaltic parting, over which the succeeding sediments have accumulated to a thickness of more than 1,500 feet. Fossil leaves found in the vicinity of the city of Ellensburg show these deposits to be of Miocene age.[1]

The Ellensburg formation occurs in the valleys, where for the most part, it is concealed under an accumulation of valley alluvium; but it is visible along the banks of the streams and where irrigation ditches have been cut down through the alluvial covering. Along the borders of the valleys the white rocks can be seen, often extending several hundred feet up the lower slopes of the ridges. Such soft rocks as these friable sandstones and shales can not well resist even the slight erosion of this arid country, so that the presence of the Ellensburg formation is frequently indicated only by the bits of andesitic pumice lying on the surface around badger holes.

The best exposure of the series is along the north side of Naches Valley, where the white bluffs extend for miles. Here the character of the rocks can easily be determined. A careful measurement of this section, made by Mr. Frank C. Calkins, who served as geologic field assistant in the survey of the Ellensburg quadrangle, is as follows:

Section of Ellensburg formation along the north side of Naches Valley.

	Feet.
Brown pumice sand, varying in texture and color, in part concealed, approximately	145
Brown pebbly sandstone or conglomerate, with small basalt pebbles in a matrix of ashy sand	100
Gray and brown sandstone and pumice sand	90
Conglomerate, andesitic pebbles, with a few basaltic pebbles, in ashy matrix	15
Brown tuffaceous sandstone, with much pumice	25
Partly consolidated sand, composed mainly of pumice grains	85
Soft light-gray ash	1

[1] Bull. U. S. Geol. Survey No. 108, p. 103.

Section of Ellensburg formation along the north side of Naches Valley—Continued.

	Feet.
Brown pumice sand	10
Porous sinter	1.5
Coarse, brown, tuffaceous sand, partly consolidated	3
Coarse, soft, gray sandstone, composed of angular andesite fragments	2
Yellowish-white pumice conglomerate	5
Fine gray sand, silt, and pumice sand well stratified	2
Coarse to fine-grained, brownish-gray, soft tuffaceous sandstone, with pumice and andesite fragments	25
Pumice conglomerates and interbedded tuffaceous sandstone	12.5
Hard, fine, gray sandstone	1
Fine brown sand, partly consolidated	3
Grayish-brown sand, with a few pumice pebbles	3
Reddish-brown conglomerate, with large bowlders	20
Hard sandstone, with calcareous layers	1
Coarse, gray, pebbly sand, cross bedded	15
Brown tuffaceous sand, with lapilli	1.5
Coarse conglomerate of andesite and pumice	5
Grayish-brown tuffaceous sandstone, with pumice pebbles	6
Well-bedded gray sandstone and shale, with pumice pebbles	18.5
Brown tuffaceous sandstone, pebbly	3
Andesite conglomerate and partly consolidated sand, with some pumice pebbles	30
Pumice and andesite conglomerates	3.5
Fine, cross-bedded, soft sandstone, with bed of angular pumice	9
Coarse pumice conglomerate	1
Fine gray sand and silt, with much pumice	4
Pebbly sand, with pumice pebbles	10
Pale-lavender soft shale	1
Gray tuff and sand	5
Light-brown fine sandstone, grading up into chocolate clay	7
Pebbly sandstone, in part tuffaceous, with intercalated layers of pumice pebbles and fragments	32
Andesitic agglomerate, fine grained	2
Medium-grained gray sandstone	4
Andesitic gravel	4
Coarse sand and gravel	5
Hard sandstone	3
Fine to coarse, medium-fine, gray and brown sands, with lapilli and pumice pebbles	28.5
Coarse sand, with bowlders stained brown	6
Medium-grained hard sandstone	3
Fine andesite gravel, with coarse sand, partly consolidated	10
Gray tuffaceous sand, with fine pumice	6
Conglomerate pebbles, averaging about 2 inches, covered with dark-brown varnish	20
Fine, light-gray, tuffaceous sandstone	2

Section of Ellensburg formation along the north side of Naches Valley—Continued.

	Feet.
Dark-gray coarse sand, cross bedded, with small andesite pebbles	5
Fine to medium-grained, light-gray, tuffaceous sandstone and silt	6.5
Andesitic agglomerate, fine grained	10
Dark-gray sand, cross bedded	1.5
Conglomerate pebbles, mostly andesite, with a few of basalt, averaging about 2 inches, obscurely cross bedded, with lenses of sand	20
Sandy tuff, with fine lapilli	6
Fine gray sand, cross bedded	1
White tuff, fine lapilli in matrix of feldspathic sand	2
Light brownish-gray ash	4
Soft sand	5
Fine white silt	8
Fine, light-gray, tuffaceous sandstone and ash, coarser in upper portion	7
Coarse agglomeratic sandstone, composed of subangular fragments of andesite interstratified with gray sandstones and pumice tuff and conglomerate	38.5
Fine tuff, light gray, structureless	4.5
Rough sandy conglomerate of andesite pebbles	5
Fine, light- to dark-gray, hard sandstone, in part cross bedded, with pumice pebbles	9
Fine light-gray sandstone and brownish tuffaceous sandstone	9
Fine light-gray tuff, with lapilli	2
Fine, light-brown, tuffaceous sandstone, structureless	4
Hard, light-gray, pebbly sandstone and interbedded tuff of fine pumice fragments	11.5
Cross-bedded, soft, gray sandstone, with abundant pumice pebbles	6
Fine andesite agglomerate, grayish brown	1.5
Cross-bedded, fine, gray sandstone and shale, with small pumice pebbles	10.5
White and lavender shale, passing into shaly sandstone above	8
Fine light- to dark-gray sandstone	10
Cross-bedded dark-gray sandstone, with pumice pebbles	3
White shale	1.2
Fine to coarse, gray, tuffaceous sandstone, structureless, with some pumice pebbles	14
White shale and fine gray sandstone, interbedded	19
Lavender and white laminated shale, in part sandy	10
Light rusty-brown agglomeratic sandstone	8
Cross-bedded sand and gravels, pebbles with blackened surfaces	8
Fine-grained gray sandstone and silt	15
Medium-grained tuff composed of lapilli	1
Light-gray sandstone grading into silt	15
Conglomerate, with large and small andesite pebbles and sand lenses	60

Section of Ellensburg formation along the north side of Naches Valley—Continued.

	Feet.
Fine, soft, gray sandstone and silt, coarser in upper portion, cross bedded	8.8
Medium-fine light-brown tuffaceous sandstone	9
Gray and greenish soft sandstone and sandy shale	10
Medium to coarse light-gray sandstone, locally grading into fine conglomerate	20
Fine, soft, light-gray sandstone and lavender shale	1.4
Coarse brown silt	4
Conglomerate, finer in lower portion	6
Coarser cross-bedded sandstone, with pebbles	6
Fine conglomerate and medium-grained light-gray sandstone	2.7
Coarse to fine, gray, cross-bedded sand	5
Lavender silt and ash, with lapilli, white above	7
Fine lapilli, unconsolidated	1
Fine light-brown sandstone	4
Coarse tuff, with rounded pumice pebbles in a sandy matrix	3
Light-gray tuffaceous sandstone, with lapilli	2
Fine andesitic agglomerate	3
Medium-grained, gray and yellow, soft, cross-bedded sandstone, with small pebbles	8
Medium to fine tuffaceous sandstone, buff colored, structureless	8
Medium to coarse-grained, cross-bedded, bluish-gray sandstone, with small pumice pebbles	12
White silt	1
Light-gray cross-bedded sandstone and silt	10
Drab and gray tuffaceous sandstone, structureless	15
Soft white tuff of fine pumice fragments	1.5
Soft tuffaceous sandstone, structureless	7
Cross-bedded gray sand, with pumice pebbles and interbedded silt	6
Fine drab sand and lavender silt, interbedded	6
Fine lavender tuff, structureless	1.3
Fine sand and clay, irregular stratification	5
Medium-grained sand, with scattering pebbles of pumice	1.5
Fine light-gray sand and lavender-colored silt	3
Dark-gray cross-bedded sandstone, with small pumice pebbles	6
Hard, grayish to brownish, medium-grained sandstone	2.5
Coarse gray sandstone and tuff, with lapilli in sandy matrix	1.5
Fine sand and lapilli, partly consolidated	1.5
Tuff, with angular fragments of andesite, pumice, and feldspar	4
Fine light-gray sandstone, with beds of silt in upper part	16
Lavender shale	1
Light-yellow ash and lavender shale, passing into fine sandstone	10
Conglomerate, with seams of sand, large andesite and pumice pebbles	10

Section of Ellensburg formation along the north side of Naches Valley—Continued.

	Feet.
Medium to coarse, cross-bedded, soft, gray sandstone, finer in upper portion	10
Lavender-colored ash, feldspathic	5
Medium-grained, light-brown to greenish, tuffaceous sandstone, with andesite and pumice pebbles	4
Cross-bedded sand, with lapilli and andesite pebbles	9
White tuff, with small angular lapilli	.5
Interbedded silt and sand, drab colored, with lapilli	7
Fine, bluish-gray, soft sandstone, with pockets of lapilli	8
Medium coarse gray sandstone	3
Lavender tuff, with a medial bed of drab-colored silt	2
Coarse sandstone, with much feldspar and fine lapilli, finer toward the top	3.5
Coarse light-gray ash	2
Medium-grained, light-gray, tuffaceous sandstone, with angular lapilli	1.8
Medium- to fine-grained gray sandstone	9
Coarse, stream-bedded, gray sandstone, with pebbles of andesite and pumice	2.8
Conglomerate, with small pebbles of andesite and larger pebbles of pumice; some sand lenses	4.5
Coarse buff-colored ash containing much feldspar	7
Gray sandstone and silt	20
Fine light-gray ash, structureless	20
Sand and gravel, stream bedded, pebbles 2 inches average diameter, gravel finer in upper portion	33
Fine gray ash, structureless, silky luster, composed of fine particles of glass	4
Fine, gray, tuffaceous sandstone, with lapilli one-fourth inch in diameter	3
Conglomerate interbedded with sand; pebbles of black andesite 1 to 4 inches in diameter	10
Basalt, two flows, columnar, with vesicular upper surfaces, 25 feet in thickness	
Gray ash	1
Light-gray tuff, with pebbles of andesite	25
Total sediments resting upon upper surface of main body of Yakima basalt	1,569.5

As will be seen from the foregoing section, the most noteworthy characteristic of the Ellensburg formation is the presence throughout of white andesitic pumice in angular pebbles and small bowlders. More compact andesitic lava is the material next in importance, while basalt is noticeably unimportant. The rare and sporadic occurrence of pebbles of basalt in this sedimentary formation is remarkable, and, as shown in the section, the basaltic material is more common near the top of the series. Another conspicuous feature is the cross bedding of the sandstones. These characters afford evidence as to the nature of the water body existing at that time and the conditions of sedimentation.

It is demonstrated that in Miocene time, immediately following the eruptions of the great basalt flows, central Washington was covered with water, but until the whole area has been studied it can not be stated how extensive or how deep this body of water was. In the North Yakima region the streams washed down vast quantities of material from adjoining areas where andesitic lava was being erupted. Stream-rounded pebbles and bowlders were thus deposited; and the deposition apparently took place in shallow water, since the stratified beds of sand and gravel show the effect of currents which could not have existed in deep waters. The beds of finer material, however, are more perfectly stratified, showing that at times deposition took place in more quiet waters.

ANDESITE.

Between the lower Naches Valley and the valley of Cowiche Creek there is a broad plateau with peculiar features. Its topography is noticeable from the presence of undrained depressions and a general hummocky surface. It is about 12 miles long, from 1½ to 3 miles wide, and from 300 to 700 feet above the valley. It represents the lower end of a lava stream which had its source in the Tieton Basin, to the west, and following down the canyon of Tieton River flowed out over the broad valley at the junction of Cowiche Creek and Naches River. The irregular though generally flat surface remains just as when the molten rock cooled, while at the edges of the old flow the columnar jointing of the cooled lava is seen. The latter feature is exhibited in a wonderful manner at Pictured Rocks. (See Pl. IV.) The rock of this plateau is an andesite which occurs nowhere else in the area here discussed. Its eruption occurred much later than the great basalt eruptions, and in fact is the latest important incident in the geologic history of the region. As this andesite area has little or no agricultural value, being too high to be supplied with water, its eruption may be regarded as of the nature of a disaster. The flood of molten rock poured into Naches Valley and doubtless converted fertile bottom land into this arid plateau.

ALLUVIUM.

The valleys of this region owe their value for agricultural purposes to the fine-grained alluvial deposits. The finest of silt extends over large areas of bottom lands, which represent the sediments that have been deposited by the streams flowing slowly upon their flood plains. In the Atanum-Moxee Valley some fine material doubtless was deposited in the ponded waters during Glacial times, when a large lake covered hundreds of square miles in central Washington, and when the large granite bowlders that are found in Wide Hollow were dropped from masses of ice floating in this lake, to which the name Lake Lewis has been given. Farther south these fine lacustrine deposits are more prominent, and can be seen at many points along the roads south of Union Gap. In fact it is this fine silt deposit which renders these roads almost impassable during the dry season. Under irrigation, however, this land becomes of great agricultural importance. Coarser alluvium, sand, and gravel cover portions of the valleys. In no place, however, are these areas of coarse material large. Such gravel flats can be seen near the junction of Naches and Yakima rivers, where they form low terraces, but even these gravel-covered areas are not without agricultural possibilities, as is proved by the orchards in the vicinity.

STRUCTURE.

The geologic structure of the North Yakima region is simple. The manner in which the rock formations are built up to form the crust of the earth, or what might be termed its architecture, is often exceedingly complicated, and in most localities the constant tearing down by atmospheric agencies most effectually conceals the plan of construction. In this region, however, owing to the arid climate, the action of running water has affected the surface very little, except where certain larger streams have cut their canyons. So it is that the configuration of the surface very clearly indicates the structure of the rocks beneath. This direct relation between topography and structure is exceptional, but its presence in the vicinity of North Yakima renders it possible to see and understand the manner in which the rocks have been folded, and consideration of the structural relations is quite essential to the discussion of the problems connected with the artesian water supply. The parallelism between the surface and the rock structure is shown in the fact that the ridges are rock arches and the valleys inverted arches or troughs. In more technical language, the ridges are anticlines and the valleys are synclines.

ARCHES.

The anticlinal structure can be observed at many places where Yakima River has cut across the ridges, as, for instance, at Union Gap, a few miles south of North Yakima, where on either side of the river the sheets of basaltic lava can be traced upward from the river level in a broad arch extending high up on the steep sides of the gap, and then down again to the river. (See Pl. V, *A*.) A similar arch is shown in the gap north of North Yakima, but there the relations are not so distinct, because the Yakima and Naches rivers in their meanders have cut away portions of the sides of the arch. Farther east, however, along Selah Ridge, the arch can be seen in its entirety. To the north, the next ridge which lies between Selah Creek and Burbank Canyon shows very plainly this same arched structure, and at many other places along Yakima River opportunity is afforded for observing, even from the car window, the geologic structure of the region.

Atanum or Yakima Ridge is one of the more prominent of the anticlinal ridges of the district, and from its proximity to the artesian-water area it deserves a few words of description. As a ridge it begins in the elevated region south of the headwaters of the South Fork of Atanum Creek; thence it extends eastward about 25 miles, to Union Gap, being well-defined, from 2 to 3 miles broad, and rising from 1,000 to 1,500 feet above the bordering valleys. Its slopes are gentle and its crest is even, with a slight eastward slope. At Union Gap, where, as already mentioned, the anticlinal structure of the ridge is plainly revealed, it is interrupted by a canyon 1 mile in length, 800 feet in depth, and as steep sided as a railroad cut. Five miles east of Union Gap there is a sudden change in the structure and in the topography of the ridge. The crest of the arch shows a distinct saddle or transverse buckle, so that a low pass is formed not more than 100 feet above Moxee Valley, to the north. Here the basalt, which is prominent on the ridge throughout its whole extent westward, drops below the surface, and the Ellensburg sandstone overlying the basalt is found in the pass where the wagon road crosses. East of this pass the arch of basalt reappears, and the ridge for the most part assumes its topographic character and extends for many miles to the southeast, where, according to Professor Russell, it finds its continuation in Rattlesnake Mountain.

Selah Ridge, north of North Yakima, is of the same type of structure as Atanum Ridge. It begins on the north side of the headwaters of Atanum Creek, forming Cowiche Mountain, a well-defined anticlinal elevation with a general east-west trend. East of Cowiche Mountain the ridge is somewhat lower, and is also cut by Cowiche Creek and Naches River. In this portion it appears to have lost much of its anticlinal character, through the undercutting of its flanks by the meanders of Yakima River, as already mentioned. East of Yakima River the full arch can be seen, and the ridge continues eastward many miles, in fact not dying out until Columbia River is reached.

Other ridges occur to the north and south of those just described, and, like them, have a general east-west trend and are, without exception, anticlinal in structure. The arches have flat crests and steep sides, so that where best exhibited the cross section is comparable to an inverted U. The steep sides of the anticline cause steep slopes of certain of these ridges, and the change from the gentle slope near the crest to the steeper slope on the side of the arch is often so sudden that a fault scarp is suggested. A careful study of these ridges in the excellent sections afforded by the gaps cut by Yakima River fails to show the presence of any extensive or important fault, and the general absence of faulting may in fact be mentioned as one of the characteristics of the region.

TROUGHS.

As already noted, in the description of the topography of the region, a conspicuous feature is the presence of long valleys, which in their medial portions are crossed by Yakima River. The correspondence between topography and structure is expressed in the noticeable fact that wherever one of these east-west valleys is seen on one side of Yakima River its continuation is to be found on the opposite side. The Atanum-Moxee Valley is such a depression, and is the most important in the present discussion, for it is there that the artesian wells are located. This valley is 40 miles long, about 6 miles wide, and has a general east-west trend, being crossed by Yakima River about midway in its length. The slope from Yakima River to either end of the valley is very gentle, and to the east Moxee Valley finds its continuation in Rattlesnake Valley, just as Atanum Ridge to the south finds its eastward continuation in Rattlesnake Mountain. The elevation of the floor of this valley in the vicinity of North Yakima is between 1,000 and 1,100 feet above sea level. The structure of the trough is best indicated by the fact that the upper beds of basalt, which occur on the surface along the crest of Atanum Ridge to the south of the Atanum-Moxee Valley at an elevation of about 2,150 feet, are found at a depth of about 1,200 feet below the surface of the valley.

The Wenas-Selah syncline is to the north of Selah Ridge. While Wenas Valley is not so plainly a valley of the same type as that already mentioned, it has an eastward continuation in Selah Valley which is exactly similar to Moxee Valley, to the south, except that the basalt is not so deep beneath the surface as in the latter valley. The valley of Roza Creek and Burbank Canyon constitutes the next synclinal valley to the north, being followed by the Umptanum-Squaw Creek Valley. In these cases the trough is well shown on both sides of Yakima River. Farther north is Kittitas Valley, a valley of the same type, in which is situated the city of Ellensburg, and which is the next area of agricultural importance to the north of North Yakima. South of North Yakima the Reservation Valley has a similar structure and the same topographic characters.

Such of these valleys as are important in the discussion of the artesian problems will be described more fully further on.

WATER RESOURCES.

In an arid region like the North Yakima country, where extensive areas are well adapted to agricultural purposes, by reason of the favoring topography, the composition and texture of the soil, and the moderately high mean annual temperature, water becomes one of the most valuable natural resources. Upon it depend land values, so that the proper conservation and utilization of the water supply is of greatest economic importance. Such a water supply is in part visible and in part concealed. The former comprises the rivers and streams, and will be discussed under the title of surface waters. The latter includes the water stored beneath the surface, or the underground water. Both have one origin, being derived from the rainfall and snowfall, the surface waters representing the run-off and the underground waters that portion which sinks beneath the surface. In an arid region neither the surface waters nor the underground waters are wholly indigenous, but are derived from adjoining areas where the precipitation is heavier, so that, in order to discuss intelligently this economic problem, observation must cover a great expanse of country.

SURFACE WATERS.

Although the area herein described lies within the Arid Region, it is close to the western border of that belt, and is, therefore, well supplied with flowing streams, which have their source in the mountains. These will be described briefly, on account of the important bearing which they have upon the subject of irrigation in these valleys.

YAKIMA RIVER.

The master stream of the area is Yakima River. East of this river the tributary streams are only seasonal, but those entering from the west are more important. These tributaries, like the Yakima, head against the snow peaks of the Cascade Range. Yakima River has its source in Keechelus Lake, close to the crest of the range. This lake is supplied with water from the surrounding peaks, on which the snow remains until late summer, and in many cases persists from year to year. Kachess and Clealum rivers are the two important headwater tributaries of the Yakima, being the outlets of large lakes of the same names. Both of these rivers are supplied throughout the summer by melting snow and glacier ice. The next large tributary is Teanaway River, which drains an extensive area to the north of Yakima Valley. Other tributaries are Swauk, Reeser, Taneum, Manastash, Wilson, and Naneum creeks, the waters of all of which are used in the irrigation of Kittitas Valley, the important broad valley in which Ellensburg is situated. In 1892 extensive plans were proposed by the Northern Pacific land department for irrigating Yakima Valley, and detailed surveys for reservoir sites were made on the three lakes mentioned. All of these lakes outlet through glacial deposits, and it was proposed by the Northern Pacific, Yakima and Kittitas Irrigation Company to construct crib dams 30 feet in height at the lake outlets. This plan, however, was not carried out, although timber for the purpose was prepared and remains piled up at the outlet of Keechelus Lake.

Several years ago a canal was proposed to take water from Yakima River at Easton, and portions of it were constructed. It is known as the Kittitas Valley irrigation canal, and if completed it would have irrigated a large portion of that valley. At present the valley, which comprises a large amount of arable land well adapted to the cultivation of alfalfa and the cereals, is irrigated solely by local ditches, which use the water from the creeks already mentioned.

One of these, Reeser Creek, receives some water which has been diverted into its channel from First Creek, one of the tributaries of Swauk Creek. This diversion is interesting, as the water is made to follow the old abandoned waterway through Green Canyon. Some attempt has also been made to improve the water supply of Manastash Creek, a small dam having been built at the outlet of Manastash Lake, so that a small amount of water is stored at that point.

Tributary streams which enter Yakima River within the area here discussed are Wenas Creek, Naches River, and Cowiche and Atanum creeks.

WENAS CREEK.

Wenas Creek drains the limited area lying south of the Manastash drainage and east of the small tributaries of Naches River. As seen on the map (fig. 1), it has a general southeasterly course and enters

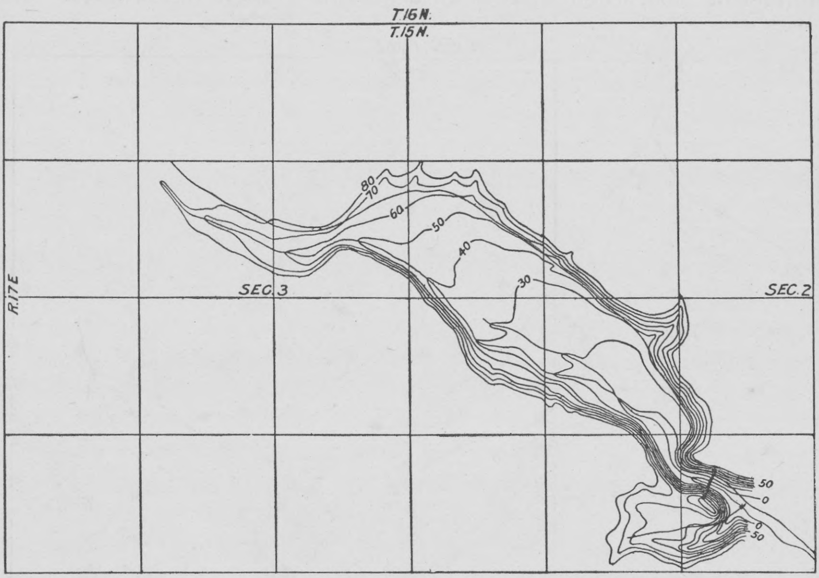


FIG. 2.—Map of reservoir site on Sherman's ranch, Wenas Creek.

Yakima River about 10 miles above the city of North Yakima. It drains a broad, fertile valley, which was early settled, being on the old stage road between The Dalles and Ellensburg, and the region beyond. Irrigation along the stream has, therefore, been developed to a considerable extent, and the ditches built effected so complete a diversion of the water during the dry seasons that lawsuits have been brought to determine a proper division of the water. The courts have ordered a more or less equitable division, but this solution of the problem is not wholly satisfactory, and attempts have been made to devise a system of storage.

The natural basin in secs. 2 and 3, T. 15 N., R. 17 E., was examined by Mr. Cyrus C. Babb in 1898. The results of the survey made at that time are given in the following table:

Capacity of reservoir site on A. L. Sherman's ranch, Wenas Creek.

Contour.	Area.	Capacity.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0.1	1	1
10	3.9	20	21
20	16.0	100	121
30	38.3	271	392
40	56.1	472	864
50	74.2	653	1,517
60	88.4	812	2,329
70	106.0	972	3,301
80	123.6	1,149	4,450

A similar investigation was made by Mr. Sydney Arnold in the summer of 1900, when what is known as the O'Neil reservoir site was

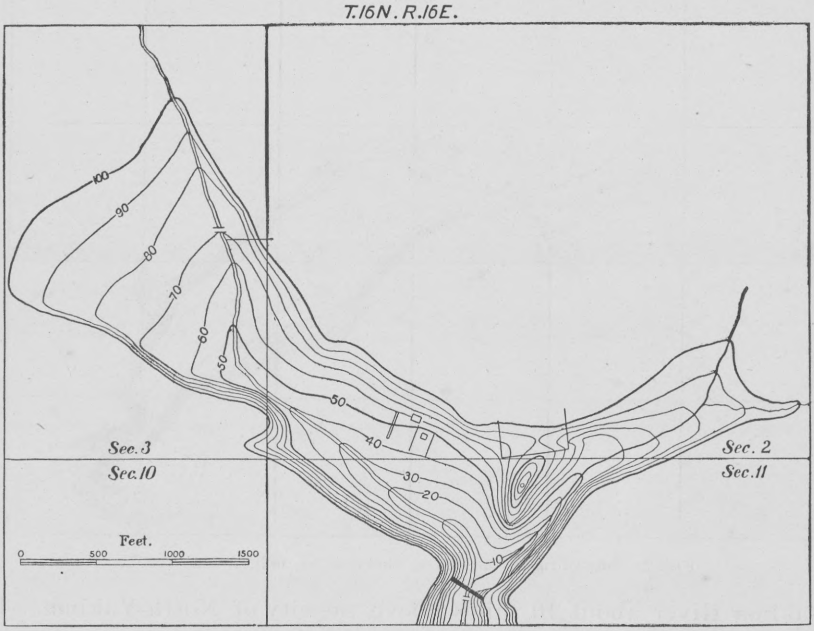
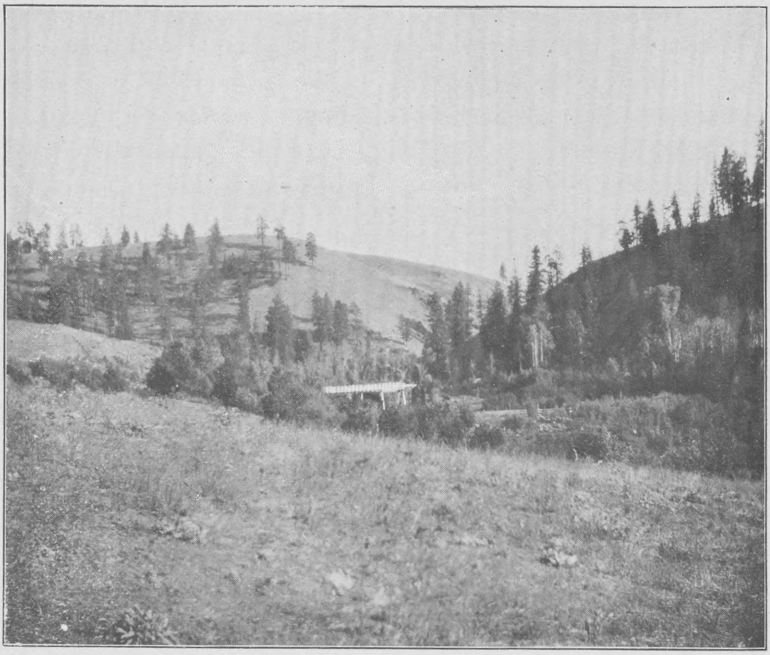
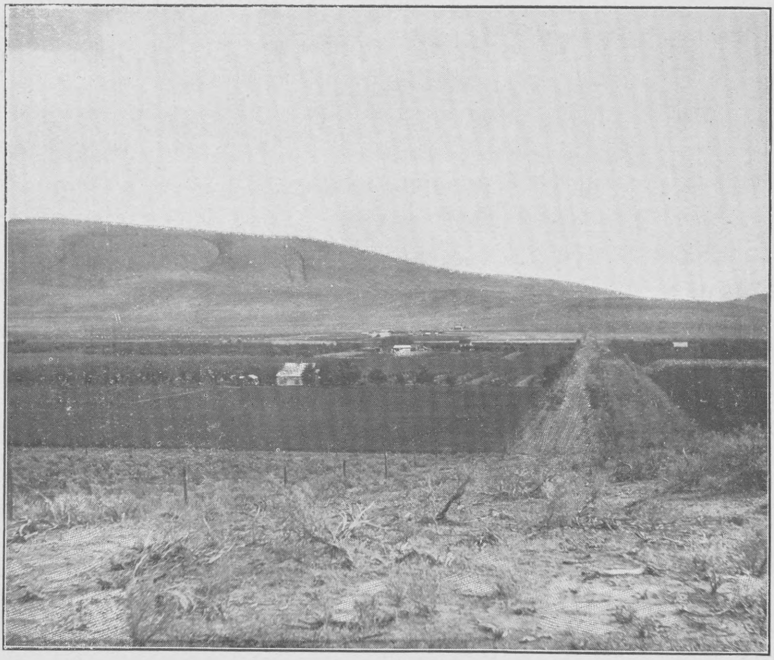


FIG. 3.—Map of O'Neil reservoir site on Wenas Creek.

surveyed. The resulting map is reproduced here (fig. 3) in 10-foot contours. The length of the dam at the base would be 90 feet; the top length at an elevation of 80 feet would be 350 feet. The total capacity of the reservoir with a dam of that height would be 1,753 acre-feet, and the capacity with a dam 100 feet high would be 3,519 acre-feet. Results of the survey are disappointing, in that the total content of the reservoir is small compared with the size of the dam required. A view of the dam site is shown in Pl. III, *A*. The fol-



A. DAM SITE OF PROPOSED O'NEIL RESERVOIR.



B. IRRIGATED LANDS ON SOUTH SIDE OF MOXEE VALLEY.

lowing table gives the capacity of a reservoir at this site for every 10-foot contour:

Capacity of O'Neil reservoir site on Wenas Creek.

Contour.	Area.	Capacity.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0	0	0
10	1.8	1	1
20	4.9	34	35
30	9.0	70	105
40	15.2	121	226
50	25.0	201	427
60	36.4	307	734
70	50.1	432	1,166
80	67.3	587	1,753
90	87.6	774	2,527
100	110.8	992	3,519

An attempt has also been made by some of the ranchers in Wenas Valley to divert waters tributary to Naches River around the southern slope of Bald Mountain into the North Fork of Wenas Creek. When seen in the summer of 1900 the ditch dug for this purpose did not appear to be a success.

NACHES RIVER.

Naches River is considered the most important stream for irrigation purposes in the State of Washington. It reaches Yakima Valley at a point where its waters are immediately available for irrigating extensive areas of the best agricultural lands. Already a number of irrigation systems take water from this river, and in view of new irrigation projects its storage possibilities have been investigated by the hydrographic division of the Geological Survey.

In the summer of 1897 Mr. Cyrus C. Babb made a survey of a reservoir site at Bumping Lake, on Bumping River. This lake, which is within the Mount Rainier Forest Reserve, lies close to the crest of the Cascade Range and is surrounded by high peaks. Its shores are covered with dense forests. On August 26, 1897, a measurement of the discharge at the outlet was made, giving 83 second-feet. At that time the water surface was 115 feet wide. The water marks around the lake show an annual fluctuation of about 3 feet. Its height may reach 7 feet during exceptionally wet seasons or after a winter of heavy snowfalls. At a height of 10 feet the water surface would be about 150 feet wide. The length of the proposed dam, at a height of 25 feet above the bed of the river, would be 480 feet. The area of the lake is 631 acres; the area at the 25-foot contour, the height of the proposed dam, is 1,153 acres, giving a reservoir capacity of 22,300 acre-feet. The Northern Pacific, Yakima and Kittitas Irrigation Company surveyed this site in September, 1894, and prepared for construction by hewing, in the immediate vicinity, tamarack timbers for the dam. These are now piled up at the outlet of the lake.

Tieton River, which enters the Naches about 15 miles above its mouth, is an important stream, and being in greater part fed by glacial streams it maintains a large discharge during the hot months of summer, when its waters are most needed for irrigation purposes.

The North Yakima region is the most extensively irrigated of any district in the State of Washington, and the importance of Naches River is shown by the canals which take water from it. Some of the principal of these may here be mentioned.

The Selah Valley irrigation canal is on the north side of Naches River, its intake being just above the mouth of Tieton River. It is about 30 miles in length, and irrigates about 3,000 acres, under cultivation, in Naches and Selah valleys. Below this, on the north side, head the Wapatuck and Naches canals, 17 and 7 miles long, respectively, which irrigate the bottom lands of Naches Valley.

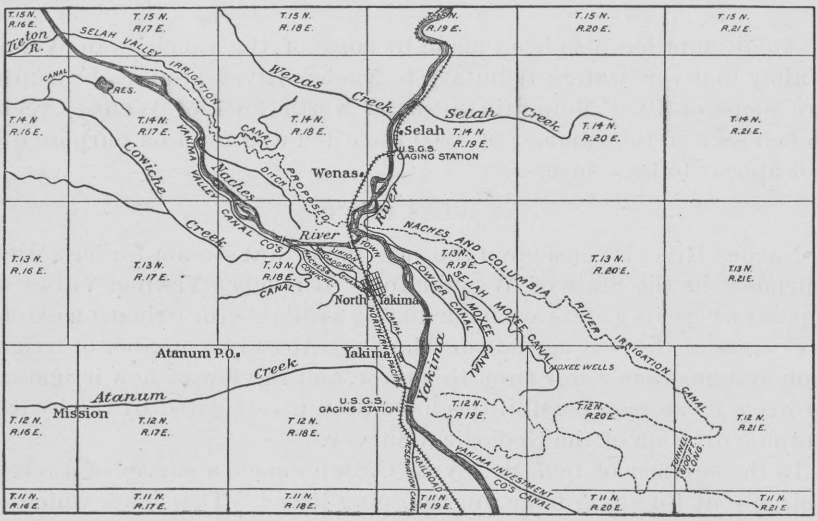


FIG. 4.—Map of vicinity of North Yakima, showing irrigation canals.

On the south side the Yakima Valley canal heads about 12 miles from North Yakima. (See Pl. IV.) For the first 10 miles of its course it is in a flume. At the high point known as Pictured Rocks it is carried around on a trestle about 70 feet high, and then crosses Cowiche Canyon in an inverted siphon; thence it continues in flume and canal around into Wide Hollow, but it has not been found expedient to extend it farther into Atanum Valley, for the reason that the canal is not high enough to cover much of the valley, and because it carries hardly sufficient water for the land now under it, for which water rights have been sold. The length of the canal is 16 miles, and it irrigates 3,000 acres.

The Hubbard ditch heads close to Pictured Rocks, on the south side of Naches River, just below the bridge crossing that stream (Pl. V, *B*). This ditch, with the Yakima Water, Light and Power Company's canal, and the Shanno, Broadgage, Union, and Town ditches, which head between the Hubbard ditch and the lower highway bridge, in the order named, serves to water the lands in the immediate vicinity

SIPHON OF YAKIMA VALLEY CANAL, COWICHE CANYON.

of the city of North Yakima. The Yakima Water, Light and Power Company's canal discharges into the reservoir, whence a drop of 20 feet is obtained, developing sufficient power for the city pumping plant and the electric lights.

In 1895 the survey for a large canal, called the Naches and Columbia River irrigation canal, was made under the direction of the State arid land commission, formed after the passage of the Carey act. The intake of this canal was to be on the north side of Naches River, 3 miles below the head of the Selah Valley canal. The canal was to cross Yakima River a short distance above the mouth of Naches River, by means of an immense inverted siphon, circle Moxee Valley, pass through the ridge east of Union Gap, by a tunnel 6,100 feet long, and continue down Yakima Valley to Rattlesnake Mountain, around which it was to pass to lands overlooking Columbia River. It was to be 140 miles long, and to carry at its head 2,000 second-feet of water. The intention was to use the Bumping Lake storage reservoir. No work has been done on this canal.

A few years ago a survey was also made for a canal called the Burlingame canal, which was to take water from the south side of Naches River, just below the mouth of Tieton River, and carry it around into Atanum Valley, thence around Atanum Ridge, to the bench lands above Toppenish Creek on the Yakima Indian Reservation. About 3 miles of construction work was done on this canal near its head. The canal as far down as Pictured Rocks would be expensive to construct, on account of the andesitic formation through which it would pass, and doubtless would be very expensive to maintain.

Mention may here be made of four canals which take water from Yakima River nearly opposite the mouth of Naches River and constitute the irrigation supply for the lower part of Moxee Valley, just southeast of the city of North Yakima. These are the Selah-Moxee canal, recently constructed,[1] the Moxee Company's canal, the Hubbard ditch, and the Fowler ditch. The last three irrigate about 3,000 acres; the Selah-Moxee irrigates about 5,000 acres.

The largest canal of the region is Sunnyside canal, which has its intake on the east side of Yakima River, about 9 miles south of North Yakima and close to the southern edge of the area included in the map (fig. 4). It is 42 miles long, and was constructed by the Yakima Investment Company, successors to the Northern Pacific, Yakima and Kittitas Irrigation Company.

COWICHE CREEK.

Cowiche Creek, which flows into Naches River about 3 miles from North Yakima, is formed by two forks which in the vicinity of their junction have rather extensive alluvial bench lands. The headwaters of these forks do not reach back far enough to secure a constant supply of water, and on this account attempts have been made to

[1] This canal was opened about June 1, 1901.

devise a storage system. The plan adopted was the construction of a reservoir on the plateau between Cowiche Creek and Naches River. A natural depression in the surface of the hard andesitic lava flow was utilized, and retaining dams were constructed, making a reservoir which can be filled during the flood season in the early spring, at which time an abundant supply of water is furnished by the North Fork of Cowiche Creek. This reservoir does not hold sufficient water to irrigate more than a very small portion of the Cowiche bottom lands, but it is of interest as it is the first of its kind in the State.

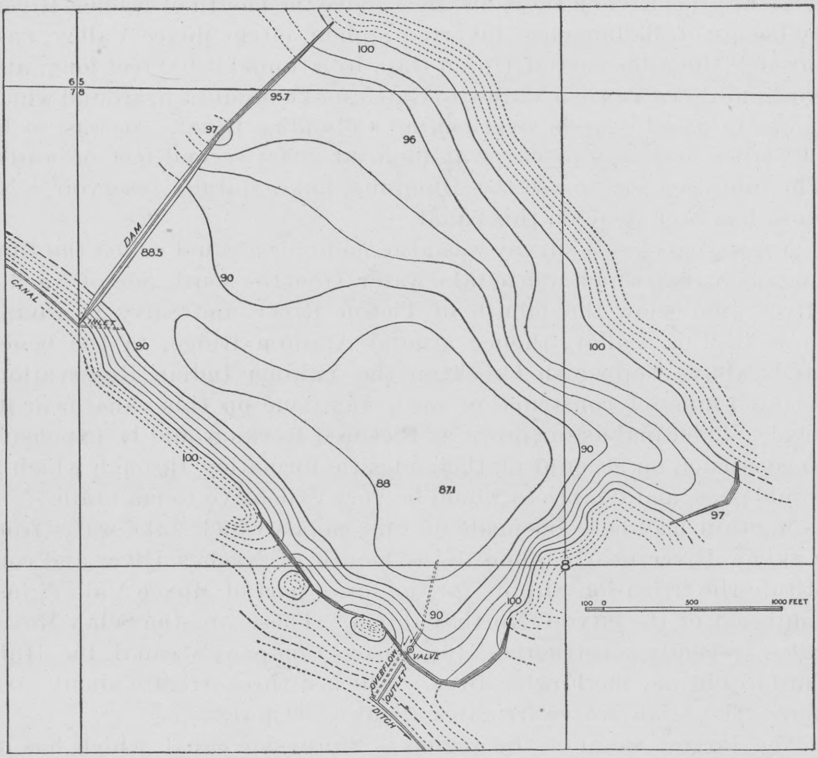


FIG. 5.—Map of Cowiche reservoir.

ATANUM CREEK.

Atanum Valley, which includes the southwestern portion of the North Yakima area, was one of the earliest sections settled in this vicinity. Here, again, nearly all of the available summer flow of the creek has been utilized for irrigation, and as a consequence a number of cases have been tried in the courts. During the season of unusually low water in 1892 an action was brought in the superior court of Yakima County, by certain riparian proprietors on Atanum Creek, "to restrain certain appropriators from diverting the water of said stream from above and conducting the same to and from their land, situated at a distance therefrom, for the purpose of irrigation." The injunction was granted, and the case was appealed to the State supreme court, where it was upheld, by decision rendered July 2, 1897. A large tract of land is under cultivation on the benches north of the river, and it would seem that under this decision irrigation will have to be discontinued unless water can be obtained from other sources.

On July 26, 1897, the discharge of Atanum Creek just below the junction of the North and South forks was 40.1 second-feet. This is above the head of most of the important canals. In July, 1897, a series of measurements of Atanum Creek and the canals taking water therefrom was made by Mr. Cyrus C. Babb, for the purpose of determining the seepage, or the amount of water returning to the creek. The following table, prepared by Mr. Babb, gives the results of these measurements:

Discharge measurements made in July, 1897, of Atanum Creek and canals taking water therefrom.

	Second-feet.
North Fork of Atanum Creek above Anderson's ranch, sec. 12, T. 12 N., R. 15 E	50.1
Cox ditch at Charles Anderson's, sec. 12	6.9
Two small ditches below Cox ditch, sec. 12	1.0
Slough at Dan Kinney's house, sec. 7, T. 12 N., R. 16 E	4.5
North Fork road bridge near Tampico, sec. 18	25.2
Waste water near Allen's house (into creek)	2.2
Atanum Creek below forks, sec. 17	40.1
Dan Lesh ditch, sec. 16	.6
Atanum Creek at Narrows, or Rocky Cliff	49.8
Herke's ditch (upper), sec. 14	.5
Herke's ditch (lower), sec. 14	.5
Morris ditch above North slough	2.5
Small Catholic Mission ditch	.3
North slough above mission, sec. 13	23.4
Atanum Creek 100 feet below Middle slough	9.0
Middle or Second slough 75 feet below head, sec. 18, T. 12 N., R. 17 E	9.8
Lynch ditch, sec. 17	.3
Yallup Indian ditch, sec. 16	8.4
Atanum Creek below Indian ditch	8.4
Simpson's ranch ditch	3.0
Woodhouse ditch	.6
Atanum Creek at Woodhouse ranch, sec. 14	.7
Atanum Creek at Tanner bridge, sec. 8, T. 12 N., R. 18 E	.8
Indian ditch, sec. 8	1.0
Atanum Creek at line between secs. 11 and 12	.9
Waste slough, sec. 1	2.5
Wide Hollow waste slough, sec. 1	14.9
Atanum Creek at Union Gap bridge, sec. 8, T. 12 N., R. 19 E	12.5

In September, 1898, a reconnaissance was made by Mr. Babb, for the purpose of thoroughly exploring the upper basin of Atanum Creek to ascertain whether there existed any possible reservoir sites in which, by the construction of suitable dams, the spring freshets of the stream could be stored and used upon the irrigable lands below during times of low water. The results of this investigation were disappointing, no reservoir sites being found.

In order to determine whether an additional water supply for Atanum Valley could not be obtained by the diversion of some of the tributaries of Klickitat River across the divide into Atanum Basin, in August, 1900, Mr. Sydney Arnold made a reconnaissance of the Klickitat Basin. Diamond Fork of Klickitat River and South Fork of Tieton River receive their waters from the peaks of Goatrock Mountains, which are covered with snow throughout the year, thus insuring a constant supply. Gold Fork of Klickitat River, the only stream to be considered in this connection, drains a lower country and has not so abundant a supply. Mr. Arnold's investigation showed the futility of any diversion from the Klickitat Basin into the Atanum Basin. Gold Fork is lower, by at least 1,000 feet, than the lowest elevation of the divide between it and the basin of Atanum Creek. The lowest point of the divide between the Tieton and Gold Fork, as shown by leveling, is lower, by several hundred feet, than any point on the Atanum-Klickitat divide, so that none of the waters of Gold Fork can be carried over to Atanum Creek.

GAGING STATIONS AND RECORDS.

A number of gaging stations have been maintained by the United States Geological Survey on Yakima River and its main tributary, Naches River. On August 14, 1893, a station was established on the latter stream at the highway bridge a short distance above its mouth. (See Pl. V, *B*.) Owing to the change in the channel, by excessive floods, the station was discontinued in 1897, but was resumed the following year, from which time continuous records have been maintained.

A gaging station on Yakima River was established at Union Gap, 7 miles below North Yakima, on August 14, 1893, but continuous records have been maintained only since August, 1896. (See Pl. V, *A*.)

In 1897 an attempt was made to obtain data regarding the flow of Naches River, and accordingly a gaging station was established on Yakima River at the Selah bridge, 4 miles above the mouth of Naches River, the idea being that the difference between the discharge at the station at Union Gap, below Naches River, and that at Selah, above the river, would give the discharge of that stream. The results were not altogether satisfactory, however, for the canals of Moxee Valley divert water between the two stations, and some waste water from the Naches River canals enters between the two points. It was for this reason that the Naches station was resumed in 1898.

The following tables give the monthly discharges at the three stations mentioned for the periods during which continuous records have been kept.

More detailed descriptions of these stations will be found in the various annual reports of the Geological Survey, Part IV, and in Water-Supply Papers Nos. 16, 28, and 38.

Estimated monthly discharge of Yakima River at Selah, Wash.

[Drainage area, 1,960 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1897.						
May 19-31	13,848	6,142	9,318	240,266	4.75	1.97
June	6,391	2,875	4,021	239,266	2.05	2.29
July	3,745	1,012	2,057	126,481	1.05	1.21
August 1-21	1,015	644	811	33,798	.41	.32
September			*a* 700	41,653	.36	.40
October 20-31	828	828	828	19,704	.42	.17
November	19,811	828	3,979	236,766	2.03	2.26
December	8,570	1,472	2,702	166,140	1.38	1.59

Estimated monthly discharge of Naches River at North Yakima, Wash.

[Drainage area, 1,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1896.						
August	1,640	490	849	52,203	0.85	0.98
September	490	350	417	24,814	.42	.47
October	450	310	347	21,336	.35	.40
November	5,200	365	1,707	104,945	1.71	1.91
December	2,950	1,450	1,940	117,071	1.94	2.24
1898.						
January			*a* 500	*a* 30,744	*a* .50	*a* .58
February			*a* 3,000	*a* 166,612	*a* 3.00	*a* 3.12
March	2,131	913	1,507	92,662	1.51	1.74
April	5,800	1,019	3,159	187,973	3.16	3.53
May	7,480	4,120	5,186	318,877	5.19	5.98
June	6,640	2,484	4,500	267,768	4.50	5.02
July	2,867	1,019	1,798	110,555	1.80	2.08
August	1,019	385	594	36,524	.59	.68
September	607	325	362	21,540	.36	.40
October	811	325	445	27,362	.45	.52
November	709	385	510	30,347	.51	.57
December	2,867	225	580	35,663	.58	.67
The year	7,480	225	1,845	1,326,627	1.85	24.89
1899.						
January	4,325	600	1,458	89,649	1.46	1.68
February	2,675	1,350	1,827	101,466	1.[illegible]3	1.91
March	1,500	950	1,115	68,559	1.[illegible]	1.29
April	3,050	1,200	2,246	133,646	2.25	2.51
May	6,700	2,500	4,534	278,785	4.53	5.22
June	6,700	5,500	6,220	370,116	6.22	6.94
July	5,800	2,850	4,606	283,212	4.00	4.61
August	2,675	950	1,605	98,688	1.60	1.84
September	950	500	666	39,630	.67	.74
October	1,500	425	728	44,763	.73	.84
November	7,300	700	2,612	155,425	2.61	2.91
December	5,500	1,200	2,941	180,835	2.94	3.39
The year	7,300	425	2,546	1,844,774	2.50	33.88
1900.						
January	6,100	1,420	2,369	145,664	2.37	2.74
February	1,550	1,000	1,199	66,589	1.20	1.25
March	4,310	1,090	2,720	167,246	2.72	3.14
April	5,200	1,690	2,953	175,716	2.95	3.29
May	5,200	1,550	3,166	194,670	3.17	3.66
June	3,010	1,090	1,806	107,464	1.81	2.02
July	1,000	470	640	393,521	.64	.74
August	530	370	423	26,009	.42	.48
September	590	390	448	26,658	.45	.50
October	2,000	390	721	44,332	.72	.83
November	1,420	910	1,189	70,750	1.19	1.33
December	5,800	1,300	2,711	166,693	2.71	3.13
The year	6,100	370	1,695	1,585,312	1.70	23.11

a Approximate.

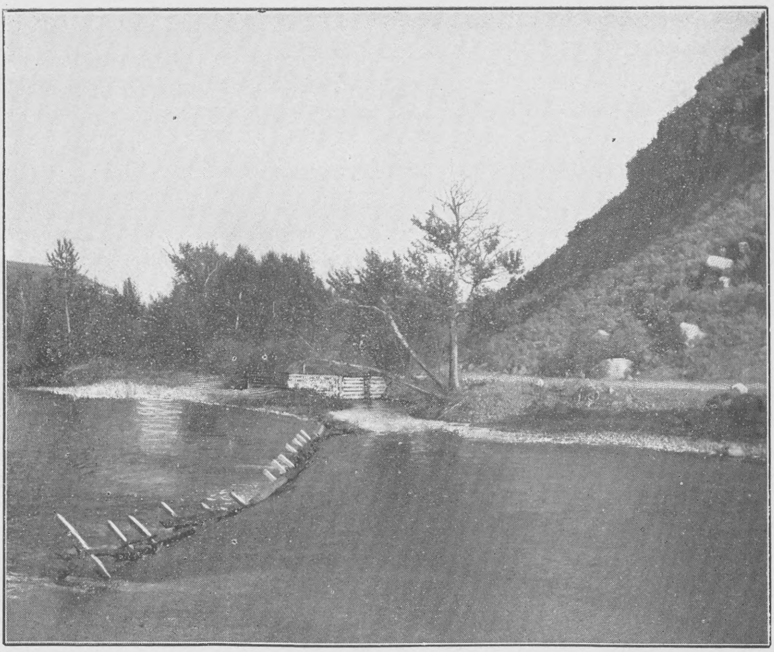
Estimated monthly discharge of Yakima River at Union Gap, Wash.

[Drainage area, 3,300 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1896.						
August	2,600	1,170	1,650	101,454	0.50	0.58
September	1,170	910	1,071	63,729	.32	.36
October	910	840	860	52,879	.26	.30
November	45,550	910	7,652	455,325	2.32	2.58
December	10,439	2,320	5,162	317,399	1.56	1.80
1897.						
January	....	....	*a* 2,100	129,125	.64	.74
February	....	....	*a* 3,000	166,612	.91	.95
March	4,738	1,650	2,472	151,998	.75	.86
April	27,550	4,738	15,004	892,798	4.55	5.07
May	23,954	11,621	15,685	964,439	4.75	5.47
June	10,826	4,738	7,109	423,014	2.15	2.40
July	6,365	1,650	3,291	202,357	1.00	1.15
August	1,440	915	1,168	71,818	.35	.40
September	915	705	817	48,615	.24	.27
October	1,020	705	810	49,805	.24	.28
November	25,135	915	5,274	313,824	1.60	1.79
December	11,220	2,320	3,969	244,046	1.20	1.38
The year	....	....	5,058	3,658,451	1.53	20.76
1898.						
January	8,270	1,894	3,350	205,985	1.02	1.18
February	22,246	1,775	6,804	377,875	2.06	2.14
March	6,969	2,818	4,538	279,033	1.38	1.59
April	12,446	3,000	6,901	410,637	2.09	2.33
May	18,500	8,270	12,388	761,713	3.75	4.33
June	15,091	5,250	9,514	566,121	2.88	3.21
July	5,250	2,170	3,480	213,978	1.05	1.21
August	2,170	885	1,364	83,870	.41	.47
September	985	685	855	50,876	.26	.29
October	1,775	685	1,300	79,934	.39	.45
November	2,644	1,315	1,971	117,282	.60	.57
December	10,059	985	1,988	122,238	.60	.69
The year	22,246	685	4,538	3,269,542	1.37	18.56
1899.						
January	10,500	2,000	4,813	295,940	1.46	1.68
February	8,050	3,500	4,810	267,134	1.45	1.51
March	3,900	2,450	3,006	184,832	.91	1.05
April	6,300	2,600	4,273	254,261	1.29	1.44
May	13,750	4,525	9,424	579,459	2.85	3.29
June	17,011	9,800	13,346	794,142	4.04	4.52
July	9,800	4,525	7,554	464,477	2.28	2.62
August	4,525	2,600	3,299	202,848	.99	1.14
September	2,450	1,605	1,920	114,248	.58	.64
October	2,900	1,355	1,888	116,089	.57	.66
November	12,030	2,300	4,711	280,324	1.42	1.58
December	14,180	2,150	5,951	365,913	1.80	2.08
The year	17,011	1,355	5,416	3,919,667	1.64	22.21
1900.						
January	19,150	4,000	8,752	538,139	2.65	3.06
February	4,800	3,060	3,770	209,375	1.14	1.19
March	11,450	3,500	7,474	459,558	2.26	2.61
April	11,800	4,800	7,747	460,978	2.35	2.62
May	10,750	3,750	7,066	434,471	2.14	2.47
June	4,800	2,800	3,828	227,782	1.16	1.29
July	2,600	1,150	1,635	100,532	.50	.58
August	1,150	650	876	53,863	.27	.31
September	1,350	850	1,090	64,859	.33	.37
October	6,600	950	2,243	137,917	.68	.78
November	4,250	2,800	3,472	206,598	1.05	1.17
December	13,550	4,250	7,092	436,070	2.15	2.48
The year	19,150	650	4,587	3,330,142	1.39	18.93

a Approximate.

A. GEOLOGICAL SURVEY GAGING STATION ON YAKIMA RIVER AT UNION GAP, WASHINGTON.



B. NACHES RIVER NEAR GAGING STATION, SHOWING WING DAM AND HEAD GATES OF NACHES AND COWICHE CANAL COMPANY.

UNDERGROUND WATERS.

GENERAL CONDITIONS.

Often the concealed water is the most important supply of a region. If the surface is hard and not well adapted to receive moisture, a large part of the rainfall is contributed to the run-off; or if the surface is poorly drained, evaporation may claim a large share. On the other hand, where the soil is sandy and open in texture, the percentage of rainfall that sinks into the ground may be considerable. The course which such waters take after their disappearance beneath the surface depends upon geologic conditions. The presence of an impervious subsoil or rock floor will cause the retention of the moisture immediately beneath the surface, where it is within the reach of vegetation, and is, through the agency of plants and the action of capillarity, brought again to the surface and eventually evaporated, never contributing to any general storage of underground waters. In the Yakima Basin these conditions are found at many localities where deposits of fine soil, of alluvial or possibly of æolian origin, directly overlie the solid basalt. The northern slope of Umptanum Ridge is a good example, and it is there that the "dry" cultivation of wheat and barley is found to be practicable.

GROUND WATER.

More commonly the water seeps through the subsoil and seeks lower levels, directed in its course by the relative porosity of the various layers of soil or rock encountered. Where the underground water is unconfined and practically free to keep its own level, it may be termed ground water. Such conditions obtain where the impervious bed simply underlies the water-carrying strata. Thus the ground water may be said to form an underground drainage system roughly comparable to the system of surface streams. In the underground system, however, there is less concentration into streams, and the rate of flow is much less rapid, since the water circulates through the minute spaces between soil particles or rock grains. Where relatively impervious rocks are traversed by joints or fissures these openings become channels for underground waters, and then the conditions are more favorable for rapid flowage than in the ordinary pore openings of the most porous rock.

The availability of the ground water is governed by geologic relations. The character and attitude of the different rock formations directly affect the position of the water table or the upper surface of the zone in which the soil and rock are saturated with water. Where porous sandstone or loose open sands and gravels overlie beds of clay or impervious rock, the zone of easy passage by the underground waters is well defined. If such water-carrying beds are near the surface they constitute the source of supply for surface wells; and if the water-saturated beds reach the surface the ground water is returned to the surface drainage system through the agency of springs. Innumerable examples of the utilization of the underground supply of water in the Yakima region could be cited. All of the surface wells of the lower valleys derive their supply from the water-saturated sands and coarser alluvium. In localities where the wells are close to the stream it is probable that the well water is derived from the underflow or underground portion of the stream. This is plainly the case where the surface stream is seasonal in character and only the underflow persists through the summer. The North Fork of Cowiche Creek is such a stream, and shallow wells have been dug in the stream bed to reach this underflow and thus insure a water supply during the dry season. As an example of the use of the available ground water in rock close to the surface, the tunnel driven horizontally into the hill slope on a ranch on Wenas Creek (sec. 11, T. 15 N., R. 17 E.) may be cited. The water which permeates the sandstone is in this manner collected and piped to the house. In the same valley these porous sandstone beds also feed numerous surface springs.

ARTESIAN WATER.

The second class of underground water is water under pressure. Where confined within a porous bed between impervious strata the

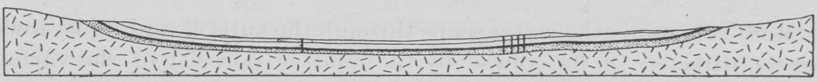


FIG. 6.—Diagrammatic section of artesian basin.

action of the water is different from that of the ground water just described. When such a water horizon is reached by a well the confined water rises and is said to be artesian, whereas ground water simply flows into a well opening, never rising above the surface of the zone of saturation. The degree to which the water possesses the artesian property is controlled by the pressure, and this is most important, since upon it depends whether the artesian well is a flowing or a pumping well. Fig. 6 illustrates an artesian basin, and shows the relation of the porous bed and the impervious strata.

The essential conditions of artesian water are geologic and topographic; that is, they involve both the underground structure and the surface configuration—the occurrence of permeable or porous rock beds or strata between other beds relatively impervious, the disposition of these strata in basin-like form, and the relatively high outcrop of the edges of the permeable strata. It will be noticed that two of these conditions depend upon geologic structure, while the third relates to the topographic features of the region.

The presence of a porous stratum between impervious strata is necessary, because it constitutes the area of accumulation or storage of underground water. The water-carrying bed may be sand or sandstone, the interstices of which afford ready passage for the circulating waters. When confined by underlying and overlying impervious rocks, such as clay, shale, or some dense and compact igneous rock, the porous stratum becomes saturated with water, which can find outlet only through the porous bed itself.

The second condition mentioned as essential is the basin or trough structure of the rock strata, shown in fig. 6. This structure is a controlling factor, because the water-carrying strata must in no place reach the surface at a lower level than the elevation of the well. A lower outlet would prevent the storage of water under pressure, with the result that the water would fail to rise in the well, in which event the supply tapped would not be artesian, but of the nature of ground water, as already explained.

The third controlling condition is the existence of an adequate source for the artesian water. The outcrop of the porous beds at the surface constitutes the area of supply or imbibition. Here surface and ground waters pass downward and enter the artesian basin or area of accumulation. To adopt a common illustration, the outcrop of the water-carrying bed may be compared to the intake of a city water main at the reservoir; thence the city's water supply is carried beneath the surface, but is available wherever a surface pipe taps the main and brings the water to the surface again, the pressure at any hydrant being directly dependent upon the elevation of the reservoir. This comparison of an artesian basin to a city water system of the gravity type may be found helpful to the practical man.

If all of the conditions specified obtain in a region, an artesian water supply is assured, and the water which is stored in the artesian basin can be tapped by a well driven through the confining cover, thus affording an outlet for the water which saturates the porous beds. The height to which the artesian water will rise in the well is dependent upon the head or pressure, which in turn is directly controlled by the elevation of the upper end of the water body, or the point where the water-saturated beds reach the surface. If the mouth of the well is relatively lower than the point where the beds receive their supply, the pressure will be sufficient to force the artesian water to the surface, and the well will be a flowing well. If, however, the mouth of the well is higher than the outcrop of the water-carrying beds, the water in the well will not reach the surface, and pumping will be necessary. Friction within the water-carrying beds and the well casing of course enters as a factor, slightly decreasing the pressure.

The facts which bear directly upon these three essentials of artesian water must be ascertained in different ways and with varying degrees of success. The area of accumulation or storage is subterranean, and therefore is known only through "logs" or well records. Geologic observations of the surrounding country—the more widely extended the better—also afford a basis for a comparatively accurate knowledge of the underground conditions. This is equally true of the second factor, the structure. Accurate mapping of the geologic formations, with careful study of their structure, enables the geologist to estimate the probability of the presence of an artesian water supply. The third condition is directly available for study, since the area of supply or outcrop of the porous beds is at the surface, and observation can be made of the areal extent of the outcrop and the amount of precipitation, which factors directly affect the supply of water and the storage area below, and a knowledge of them is necessary to any discussion of the amount and constancy of an artesian water supply.

ARTESIAN BASINS.

In the light of the foregoing discussion of general principles it may be well to describe now certain areas of central Washington which possess, or are thought to possess, artesian water. At present there is known within this region no artesian basin which can be compared to such basins in other parts of the country. As before stated, central Washington is unique in the geologic structure of its mountain ridges and valleys. The conditions which exist in the one known artesian basin are peculiar, and for that reason require special consideration. The presence of a supply of artesian water where it could hardly be expected renders careful study of the geologic conditions imperative. To this end a description of the Atanum-Moxee Basin is necessary, and the knowledge that is acquired from a study of that artesian basin can be applied to the other areas where water is desired.

ATANUM-MOXEE BASIN.

The Atanum and Moxee valleys occupy the synclinal fold or trough described on page 25. The structure of this composite valley becomes its most important feature in relation to its value as an artesian basin, and it will be seen to possess the form essential to make it a reservoir for artesian water. The valley itself may be described as canoe shaped, but the trough structure of the underlying rocks is more accentuated, and may better be compared to a flat-bottomed scow. For 15 or more miles along the central part of this rock fold the beds have little slope or dip, but at each end there is a rather sudden change to an upward slope. Thus, while 5 miles east or west of Yakima River the base of the Ellensburg sandstone or the top of the Yakima basalt is at a depth of from 1,000 to 1,200 feet, a few miles beyond it is much nearer the surface. In Atanum Valley the slope of the bottom of this rock trough is known from a well record and from surface observations. Less than 2 miles east of the village of Atanum the upper surface of the basalt is more than 1,200 feet beneath the valley floor, while 6 miles west of that place the basalt appears at the surface. This represents a total upward slope at this end of the trough of more than 1,700 feet, while west of Tampico the basalt sheets slope upward even more rapidly, until the top of the inclosing ridge is reached. The outcrop of the basalt for a few miles along Atanum Creek below Tampico is due to a step-like interruption in the general eastward slope of the rocks at that point. This is important, as will be explained further on, because the water horizon near the base of the Ellensburg sandstone is here brought to the surface.

At the sides of the Atanum-Moxee Basin the upward slope of both the surface and the rock beds is quite abrupt, but the dip of the rocks is steeper than the slope of the surface. In the vicinity of Union Gap and westward for a few miles along the southern wall of the basin, the Ellensburg sandstone, wherever observed, is sharply upturned, and dips of 50° to 80° can be seen, while at a few points the rocks stand in a vertical position or are slightly overturned. This is also true on the north side of Wide Hollow, near Naches River.

While this area has the essential basin structure, it will be noticed at once that Yakima River has cut across the rim of the basin at points approximating 1,000 feet above sea level. At that level, then, the lower beds of the Ellensburg formation occur under the alluvium of the river bed, and, since these beds constitute the water horizon, it presumably would follow that the artesian basin would be tapped at that level. Furthermore, these being the lowest points in the Atanum-Moxee Valley, no flowing wells could reasonably be thought possible there; but such wells do exist, and will be described further on, and as they occur more than 100 feet higher than the sea level, it is evident that the artesian basin is not tapped.

So anomalous a condition of course requires an explanation. Two hypotheses may be advanced to account for the absence of leakage at the river level. The cover of fine alluvium may be so impervious as effectually to seal the exposed edges of the water-carrying beds. It has been recognized that the fine-grained sediment of the flood plains of a river sometimes is so firmly compacted as to be practically impervious. In view of the fact, however, that surface springs occur along some of the creeks in this vicinity, it seems hardly probable that the alluvium of Yakima River is sufficiently compact to prevent the upward passage of artesian water with the pressure that it is known to possess elsewhere in the basin. An explanation of this sealing up of the lower beds of the Ellensburg formation is more probably to be found in the structure of the synclinal fold. The steep dips observed along the sides of this fold in the vicinity of Yakima River is evidence of a certain degree of compression of the fold. Especially is this apparent where the lower strata are overturned. Such lateral pressure must have its effect upon the rocks, and it appears quite probable that the sandstone, which in other parts of the basin is open textured and porous, may here have become so compacted as to be relatively impervious.[1] In this way the lower strata, which constitute the water horizon along the bottom of the trough, are so changed in character along the sides as to cease to be water-bearing. Were it not for this feature the artesian basin would be drained at about 1,000 feet above sea level, and flowing wells would be possible at no point within the Atanum-Moxee Valley. As it is, however, more than a score of wells with flowing water prove the value and importance of this artesian basin. These wells will be described in a later section.

The structure of the basin in the immediate vicinity of the Moxee wells can best be illustrated by deformation contours. Fig. 7 (p. 48) shows, by means of contours or lines of equal elevations, the elevation above sea level of the lowest water-carrying beds, which mark approximately the base of the Ellensburg formation. The depths at which the water horizon is found in the different wells, together with observations made along the sides of the valley, constitute the basis for this map. It will be noticed that the syncline is unsymmetrical, having a steep side on the south and a gentle slope on the north.

WENAS-SELAH BASIN.

This transverse valley, as already noted, has somewhat the same general topographic and structural relations as the Atanum-Moxee Valley. The points of difference, however, are those which are most important with reference to the artesian water supply. The synclinal fold of this valley is much more shallow and gentle than the Atanum-Moxee trough. Taking the upper surface of the Yakima basalt as a datum plane, the lowest part of the Wenas-Selah syncline is not much below 1,000 feet above sea level, whereas in the Atanum-Moxee fold the basalt surface at its lowest point is undoubtedly considerably below sea level. This difference is significant, since it means that Yakima River not only cuts across the sides of the fold, but has cut down almost to the base of the Ellensburg sandstone along the bottom of the trough. Of course such a relation involves a draining of the basin by the river, since, as in all of these transverse folds, the lowest portion of the syncline appears to be in the vicinity of Yakima River.

As can be seen on the geologic map (Pl. II), east of Yakima River the syncline is so high, with reference to the river, that the Ellensburg formation is largely wanting, and the valley is floored with basalt. West of the river the Ellensburg sandstone is present in great thickness, and it is in this syncline that the section given on pages 17 to 21 was measured. In the valley of Wenas Creek the geologic

[1] This hypothesis is supported by the occurrence of sandstone northwest of North Yakima, at a point where the lower beds of sandstone are overturned. There it is compact enough to be quarried for building stone. Along the bottom of the trough these same beds are represented by soft sandstone and loose sand which in places is almost a quicksand.

relations at first sight seem to warrant investigation. The sandstone series extends upward on the ridge to the north, while to the south the same formation rises in high cliffs. The basin structure is present, with the elevated outcrop of the water-bearing beds; but again it is to be noted that the stream occupying this synclinal valley has cut down to very near the base of the Ellensburg, and in fact reaches it near where the main Wenas-North Yakima road turns southward and crosses the creek at the Cleman ranch.

In 1900 some work was done toward sinking a well on the Stauffer ranch, in Wenas Valley (sec. 34, T. 15, R. 18). The elevation of this well is approximately 1,500 feet, and it was sunk about 400 feet in Ellensburg sandstone. Ground water in good amount was found at a depth of 152 feet. The depth to which the sandstone was found to extend points to a shallow basin existing between the southern slope of the anticlinal ridge north of Wenas Valley and the exposure of basalt along the creek 2½ miles southeast of the well. Any water in this basin, however, would find a surface outlet near the creek level, so that no artesian supply would exist to be tapped by a well having an elevation of 1,500 feet. These relations are therefore unfavorable, and the statements that have been made are corroborated by the occurrence of large springs near Wenas Creek, on the Cleman ranch, at just the point where the lowest beds of sandstone must reach the alluvium-covered valley floor. Mr. Cleman states that the water of these springs is much warmer than the creek water. As mentioned on page 38, surface springs occur elsewhere along this creek, affording further evidence that the water of the sandstone finds a natural outlet throughout the length of this valley and is not stored in an artesian basin. It is indeed probable that if the water could be shut off in the upper part of Wenas Valley, the contributions from springs in the lower valley would be sufficient to maintain a small stream in the lower course of the creek.

There is a possibility that water may be stored in the lowest beds of sandstone which underlie the latest flow of Yakima basalt. These beds are exposed on the ridge north of Wenas Creek. As this sheet is at least 100 feet thick at this locality, it is quite doubtful whether the expense of penetrating it would be warranted by the prospect of finding water below, especially in view of the fact that the bed of sandstone beneath the basalt is often only a few feet thick and would not carry any considerable amount of artesian water. Furthermore, since the lower bed is cut by Yakima River on the north side of Selah Ridge, it is quite possible that the water content of this bed is also tapped and that artesian conditions do not obtain.

RYE GRASS FLAT.

On the north side of Selah Valley there is a smaller valley, known locally as Rye Grass Flat. As can be seen on the map, Pl. II, this flat is separated from the main valley by a low ridge, across which, however, a small seasonal stream has cut a narrow channel. As is universally true in this region, the topographic valley occupies a structural basin which is well defined. Along the southern and southwestern slopes of this basin the Ellensburg sandstone and shale plainly outcrop, with northern and northeastern dips of about 20 degrees. Several hundred feet of the Ellensburg formation are thus exposed, underlain by the basalt which forms the inclosing ridges. On the north side of the basin the sandstone is seen dipping to the south, but at a much lower angle.

In the summer of 1900 a well was driven to a depth of 270 feet in sec. 15, T. 14, R. 20, near the western end of Rye Grass Flat. At 54 feet surface water was found in what appeared to be alluvium. Here the fine alluvium or soil is 18 feet deep, with bowlders below. In its lower portion this well is undoubtedly in the Ellensburg sandstone, but it has not reached the lowest beds. The basin structure is favorable to the storage of artesian water, and where the well is located the drainage outlet of the valley is not so low as to prevent the water rising to within a short distance of the surface. The stream, however, appears to receive some water from this basin in even the middle of summer, and it is therefore quite doubtful whether the conditions are favorable for a flowing well. The well will undoubtedly be continued to a greater depth, as the search for artesian water in Rye Grass Flat is well worth the necessary expenditure, since there is considerable land of excellent quality that would become very valuable if water could be found.

COWICHE VALLEY.

The valley of Cowiche Creek contains several thousand acres of land that only requires water to make it valuable. Barley and wheat are raised there without water, but only with a moderate degree of success. On several ranches along the south fork of the creek irrigation is practicable and excellent crops of alfalfa are raised. On the north fork of the creek attempts have been made at a few points to store the waters that flow so abundantly in the spring months, and surface wells have also been dug and windmills erected.

Study of the geologic relations of this topographic basin shows that it is not in any sense an artesian basin. As can be seen, it is in reality only a portion of the large synclinal valley that lies north of Cowiche Mountain and Selah Ridge. The valley is inclosed on the northeast by the andesite plateau, but this is merely a surface flow superimposed upon the eroded surface of the Ellensburg sandstone, and therefore offers no obstruction to the flow of underground water within the sandstone beds. The conditions are therefore unfavorable for finding artesian water. However, the supply of ground water on the lower levels of the valley may be further drawn upon, while the strength of the prevailing winds of summer appears to be very favorable for windmill irrigation.

OTHER AREAS IN CENTRAL WASHINGTON.

At several other localities in central Washington attempts have been made to find artesian water. So far as the areas come within the region the geology of which has been described in this paper, the foregoing discussion may be helpful in suggesting the probability of finding water, and the few general statements which follow may aid in deciding whether or not to prospect for it.

The Ellensburg sandstone is the water-carrying formation, and generally the best water horizon is found near its base. The transverse synclinal valleys along Yakima River would possess a structure favorable to the collection and storage of underground waters were it not that the river has cut across their lowest parts, so that only under exceptional circumstances are they artesian basins. The great thickness of the Yakima basalt makes it inadvisable to prospect for artesian water in that formation. While it is often in the basalt areas that there is the greatest need of water, the chance of finding artesian water in it is far too small to warrant the great expenditure that would be necessary. The springs found along the flanks of the basalt ridge are almost without exception cold-water springs, and therefore do not point to any deep-seated supply.

The only other area that deserves special mention is Kittitas Valley. This broad valley has the basin structure, and from its great extent it appears well suited to the accumulation of underground waters. The water-bearing beds extend up on the slopes of the inclosing ridges, and must receive contributions from the precipitation over a large area. In the central part of the valley the water horizon lies at a depth of several hundred feet. As reported by Professor Russell,[1] the Sanders well, an experimental well about 2 miles northwest of Ellensburg, reached basalt at about 700 feet. When abandoned it had water at 40 feet below the surface. The evidence which it afforded was unfavorable, yet it is quite possible that this well, like many others, was drilled by an inefficient well man, and that the record is untrustworthy. The loss of tools is sometimes the occasion for falsifying the log, in order that the well may be abandoned without loss to the operator.

At the Clerf Spring, at the east end of the valley, water with considerable pressure is found flowing upward through the basalt. In the summer of 1900 the drilling of a well was commenced in the immediate vicinity of this artesian spring, about 10 feet higher, and it seems probable that not far from the surface water will be found which can be used to augment the stream already issuing from the spring. The spring has also been enlarged, its flow being increased fourfold.

[1] Bull. U. S. Geol. Survey No. 108, p. 69.

The water is seen to issue from crevices in the sandstone and the honeycombed basalt beneath. It has a temperature of 68°, and may be derived from interstratified sandstone beneath an upper sheet of basalt. If any considerable flow of water is developed at this locality it can all be used to good advantage in the eastern part of Kittitas Valley.

The gap where Yakima River cuts through the rim of the Kittitas Basin, 5 miles below Ellensburg, is of course the critical point in the structure of the basin. The exposures of the Ellensburg sandstone at this locality are poor, but they are sufficient to show that the lower beds are sharply upturned. Immediately south of the edge of the valley a transverse fault gives further evidence of marked dynamic action on this side of the basin. Whether this is sufficient to prevent tapping the artesian basin, as appears to be the case at Union Gap, south of the Atanum-Moxee Basin, can not definitely be stated. The possibility of a true artesian basin being found to exist here appears, however, sufficient to encourage the drilling of another experimental well in Kittitas Valley. This should not be done by a tyro, but by the most experienced and reliable well man available.

Larger irrigation canals taking water from upper Yakima River may possibly be built in the future, which would obviate the necessity for artesian water in this valley, in which event it would not be economical to expend any money in searching for an artesian supply.

ARTESIAN WELLS OF ATANUM-MOXEE BASIN.

GENERAL FEATURES.

Within ten years more than thirty artesian wells have been put down in Moxee Valley. As can be seen from the accompanying map, fig. 7, the principal wells are within an area of about 6 square miles. They are from about 600 to more than 1,000 feet in depth, and have flows varying from 0.05 to 2 second-feet. The water is warm, ranging from 67° to 76° F. Sulphureted hydrogen can usually be detected in it, but not in any great quantity, and being clear and apparently free from other impurities, it is used for domestic purposes as well as for irrigation. Owing to the temperature of the artesian water, in winter the cattle prefer it to stream water.

The wells show varying degrees of skill on the part of the well borers. In general they have been cased only as demanded in the progress of sinking them, and often the casing has been drawn in order to save it. Such economy is likely to be followed by a loss of flow through leakage or caving. Many of the wells have not been located so as best to serve the purposes of irrigation. It is worth noting, however, that the tendency in this region is toward greater care in the sinking of artesian wells, and the latest wells are much superior to those put down earlier.

The logs of the wells, when preserved, have little value as records of the beds penetrated by the bit. The fineness of the material brought to the surface prevents very accurate determination, and often the designation of the beds as shale, sandstone, or basalt is purely a guess based upon the rate of progress made by the drill. The attempt to use these records to construct a general section of the Ellensburg formation under Moxee Valley has proved fruitless, and on that account the logs are omitted from this report. In many logs basalt is reported at several horizons, whereas along the slopes of the ridges bordering the valley only one sheet of basalt is known to be interbedded with the sandstone. It is very probable that some of the conglomerates of the Ellensburg formation, containing, as they do, large bowlders of hard andesite, as well as some of basalt itself, have been mistaken for basalt.

The logs which record the depth at which the different flows of water are tapped are more valuable. While data on this subject can not be obtained for every well in the valley, the information available is sufficient to show that it is possible to correlate the different flows tapped by wells some distance apart. The water horizons thus indicated appear to afford trustworthy data for the determination of the form of the basin.

The table on page 49 shows the relative position of the various flows in some of the wells. From this table it will be seen that the first principal flow and the lowest flow are separated by intervals of from 148 to 235 feet, and these principal flows can be recognized throughout the field. Smaller flows occur between these two, but they do not seem to be so persistent. In certain of the wells small flows also were encountered above the first principal flow, even within 180 and 200 feet of the surface.

The plat (fig. 7) showing deformation contours is based in large part upon these well records, and shows in a graphic manner the configuration of the floor of the artesian basin. The local ridge along the center of this basin, in sections 8 and 9, has been noticed by well men, since there the water horizons are found nearer the surface. Reference to this map will show that there is a westward dip of the water horizon, amounting to about 300 feet in the mile along the line between sections 5 and 8. The deformation also shows how the Clark well in section 31, and the Sauve well in section 8, reach the water horizon at almost exactly the same level. A glance at the map will show why the well in section 12, near the west line of section 7 of the next township east, as stated further on, did not find water at a depth of 700 feet. The lower water horizon is probably several hundred feet below sea level, so that even the upper flow could not be expected at a depth less than 1,000 feet, and it seems quite possible that this well might be deepened 500 feet before water is obtained. It should be stated that this map, showing the position of the water horizon or lower flow, is based upon so scanty data that it must not be considered as showing the exact elevation of the floor of the basin, but only its approximate position and general form.

DESCRIPTIONS OF WELLS.

The table on the next page is a list of the principal wells, with the more important data concerning them. Fig. 7 will assist in locating the wells. Several of the earlier ones have been omitted from the map and from the list, since they have ceased to flow or are so nearly dry as to be of little value. The wells which are dry are outside of the area of flowing wells in sec. 32, T. 13, and in secs. 3, 4, and 10,

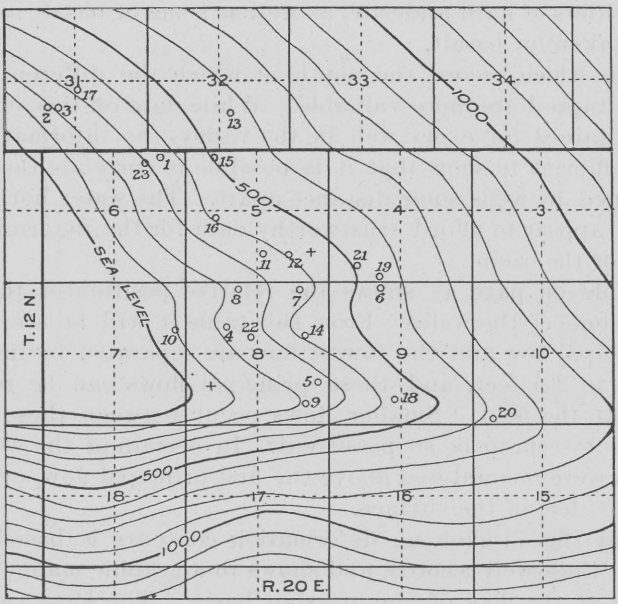


FIG. 7.—Plat showing form of Moxee Basin and location of artesian wells.

T. 12. With one exception the elevations of the wells are approximate, being based on aneroid measurements referred to the United States Geological Survey bench mark at North Yakima, which is 1,067 feet above sea level. The elevation of the Wilson well in Wide Hollow was accurately determined by a level line run by Mr. Sydney Arnold, connecting with the United States Geological Survey bench mark 1066, 4 miles east of Atanum. The location of this well is outside of the Moxee area, but it can be seen by reference to the general map, Pl. II. The measurements of flow were made in April, 1901, by Mr. Sydney Arnold, a weir being used except where otherwise stated. The numbers of the wells given in the table correspond with the numbers on the map.

List of wells in Atanum-Moxee Basin.

No.	Name of well.	Location.			Approximate elevation.	Depth.	Flow.	Depth to principal flows.				Temperature of water.
		Sec.	T.	R.								
					Feet.	*Feet.*	*Sec.-ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Deg. F.*
1	Clark No. 1	6	12	20	1,110	940	1.34	700	(?)	(?)	(?)	73.2
2	Clark No. 2	31	13	20	1,130	1,026	.15	800	(?)	(?)	1,000	76.2
3	Clark No. 3	31	13	20	1,120	1,000	.52	......	......	......	......	75.6
4	Longevin No. 1	8	12	20	1,070	637	.40	637	......	......	......	72.2
5	Haines	8	12	20	1,145	902	.984	702	760	790	902	72.2
6	Bradford	9	12	20	1,155	623	.904	386	......	623	......	73.2
7	Dickson	8	12	20	1,095	525	(*a*)	515	......	......	......	70.7
8	Gano	8	12	20	1,075	851	(*a*)	649	......	851	......	76.0
9	Sauve	8	12	20	1,155	1,020	.475	832	(?)	(?)	1,020	75.2
10	Ellens No. 1	7	12	20	1,065	835	.13	835	......	......	......	73.2
11	Holland No. 1	5	12	20	1,100	736	*b* 2.00	588	688	736	......	76.0
12	Regimbal	5	12	20	1,105	689	1.09	525	640	686	......	73.2
13	Buwalda	32	13	20	1,150	653	.05	424	508	550	600	67.2
14	Ellens No. 2	8	12	20	1,100	676	(*a*)	424	504	657	......	......
15	Buwalda and Haines	5	12	20	1,140	636	*b* .566	475	575	636	......	69.2
16	Holland No. 2	5	12	20	1,115	686	.35	520	620	686	......	74.7
17	Clark No. 4	31	13	20	1,140	960	.197	660	770	820	......	73.2
18	Allwardt	9	12	20	1,185	809	.64	......	{615 *c* to 718}	752	......	72.2
19	Deeringhoff	4	12	20	1,165	625	......	390	......	625	......	73.2
20	Rein	10	12	20	1,195	631	.485	+630	......	......	......	66.3
21	Hill	4	12	20	1,170	225	......	206	......	......	......	......
22	Longevin No. 2	8	12	20	1,080	836	.807	530	(?)	820	......	72.7
23	Peck	6	12	20	1,105	818	*b* 1.10	620	(?)	818	......	......
24	Wilson	29	13	18	1,165	1,267	*d* .75	800	1,000	1,050	......	80.0

a Well closed April, 1901.
b Approximate measurement with current meter.
c Six flows.
d Estimated.

Most of these wells deserve further description, and for this purpose they have been grouped according to locality, and will be discussed in the order of the section in which they are situated, beginning with sec. 4, T. 12 N., R. 20 E.

WELLS IN SEC. 4, T. 12, R. 20.

The Deeringhoff well, No. 19 of list, is the more important well in this section. It was completed in April, 1900. At that time the water rose 36 feet in an open pipe, and the flow reported was 56 cubic inches, but it is thought to have since diminished somewhat. The well is cased from 200 feet below the surface to 535 feet, thus cutting off the first flow. The casing ranges from 5⅝ inches to 3 inches.

The other well in this section is No. 21, the Hill well. This well was drilled by Mr. Stone, the former owner of the land, but was not completed, owing to the loss of the drill. At 206 feet a small flow was tapped, which is used.

WELLS IN SEC. 5, T. 12, R. 20.

This section contains four of the more important wells of the valley. Well No. 12 is on the ranch of F. Regimbal, being located near the northeast corner of the southwest quarter of the southeast quarter. It was put down by Messrs. Buwalda and Hainès, in 1898, and taps three flows. There is a casing through 260 feet of sand, but this is above the first flow, so that none of the flows which are in sand and sandstone are cased.

Well No. 11 is in the northwest corner of the same 40-acre lot, and was drilled the same year by Buwalda and Haines. This well is cased for 344 feet in its upper portion, but in the summer of 1900 there was considerable leakage around the casing, a trouble that it will be difficult to remedy. The three flows are not cased. The well belongs to the Holland Company.

Well No. 16 is near the northeast corner of the northwest quarter of the southwest quarter of the section. This well was completed in 1899. Shale in the upper portion of the well caved, so that 4½-inch casing was put down as far as 490 feet. The three flows are not cased.

Well No. 15 is on the fractional northwest 40 acres of this section. It was completed in June, 1899, by Buwalda and Haines, and is owned by a company. The stock is divided into 6 shares, each share supposed to represent water for 20 acres. The three flows are tapped by this well and are not cased.

A new well, indicated by the cross on the map, is being drilled east of the Regimbal well. In March, 1901, it was reported to be down 347 feet.

WELLS IN SEC. 6, T. 12, R. 20.

The two wells in this section are very important, one being almost the oldest well in the district, and the other being the last one completed.

The Clark well No. 1, as it is termed, is not far from the northeast corner of the section. Pl. VI shows the appearance of this well when completed, in 1893, as photographed by E. E. James, of North Yakima. Unfortunately, exact measurements of the flow and pressure at the time of its completion are lacking. In 1897 Mr. Clark reported its discharge to be 120 miners' inches. The testimony of those who have known the well for several years is to the effect that there has been considerable decrease in pressure and flow. In April, 1899, Mr. Sidney Arnold found the discharge to be 1.435 second-feet. This well taps the three principal flows, and is 6 inches in diameter at the mouth. The smallest casing is 4½ inches. The well cost $2,000.

The Peck well, No. 23, is about 200 yards west of Clark well No. 1, in the next quarter. This was not completed at the time of the field work, but Mr. Haines, who drilled it, reported it finished early in the present year (1901). It taps the same flows as the Clark well, but at slightly greater depths. This shows the western dip of the water horizons, and accords with the basin structure shown in the other sections.

WELL IN SEC. 7, T. 12, R. 20.

Well No. 10, the only well in this section, is close to the east line of the section. It was put down in 1899, by Mr. Ellens, the former

CLARK WELL NO. 1, MOXEE VALLEY

superintendent of the Holland Company. It is cased, but has only a small flow. The pressure is sufficient to raise the water in a 2-inch pipe high enough to carry it into the house on the Holland ranch.

WELLS IN SEC. 8, T. 12, R. 20.

This is the section with the greatest number of wells, having seven already down and one being drilled in February, 1901.

Well No. 4, on Mr. Longevin's ranch, is the oldest well in the section. It was drilled in 1893, and is comparatively shallow, tapping the first flow only. It is a small well, being only 3 inches in diameter.

Well No. 22, farther east on the same ranch, is deeper and penetrates to the third flow. This well is cased down to a depth of 730 feet, the first and second flows being shut off. It was drilled in 1900 by Mr. C. H. Haines.

Well No. 5 is near the east line of the section, on the ranch of Mr. Haines. It was completed to a depth of 702 feet in 1896, but was deepened later, and now taps four flows. It is cased, with casing from 6 to 4 inches in diameter, as far as 890 feet. The casing is split at the first, second, and third flows, all of which are in the 4-inch casing.

Well No. 9 is in the southeast quarter of the southeast quarter, on the ranch of J. Sauve. It was driven to a depth of 835 feet in 1897, by Mr. H. J. Spratt, but was deepened in 1899 and 1900, by Mr. Haines, to 1,020 feet, with the effect of approximately doubling the flow. The casing at the bottom is only 2 inches in diameter.

Ellens well No. 2, No. 14 of the list, is in the southeast quarter of the northeast quarter of this section. It taps three small flows, and is not cased below 225 feet.

The N. J. Dickson well, No. 7, is in the northeast quarter of the northeast quarter, and was put down in 1897. It is the shallowest well of the district, and taps the first flow only, but it has a good volume, which is said by the owner to have increased since the other wells in the vicinity have been deepened to tap the lower flows. This well cost about $500.

Well No. 8 is nearly a half mile west of the Dickson well, on the ranch of James W. Gano. It was drilled in 1897 to a depth of 649 feet, where it tapped the first flow. The pressure was sufficient to raise the water 30 feet in an open pipe. Pl. VII is from a photograph of the well taken at that time. In 1900 this well was deepened to 851 feet, so that now it is supplied with water from both of the principal flows.

The new well in this section is in the northwest quarter of the southwest quarter. In March, 1901, it was reported to be down 640 feet.

WELLS IN SEC. 9, T. 12, R. 20.

The Bradford well, No. 6, is close to the north line of the section and only a few yards distant from well No. 19, in section 4. It was drilled in 1897 to a depth of 386 feet, and in 1900 was deepened to 623 feet. The casing is 6, $4\frac{1}{2}$, and $3\frac{1}{2}$ inches in diameter. This is one of the few wells in the district provided with a valve by which the water can be shut off when not needed for irrigation.

Well No. 18 is on the Allwardt ranch, in the southwest quarter of the section. This well was drilled by Mr. Deeringhoff in 1899. Casing from $6\frac{5}{8}$ to 4 inches in diameter extends to a depth of 730 feet, shutting off six small upper flows. The well appears to be in good condition. The flow is strong, and the well is so situated as to enable the water to be used to advantage.

WELLS IN SEC. 10, T. 12, R. 20.

Well No. 20 is near the southwest corner of this section. It was drilled by Mr. R. Rein, but is incomplete, although it has a small flow. The water from this well is the coolest artesian water in Moxee Valley, having a temperature of 66.3° F.

The three Steinway wells are in the southeastern part of this section. They were drilled in 1894 and 1895, but now are practically dry. One, however, flows a little. One of these wells was cased down to within 30 feet of the third flow.

WELLS IN SEC. 31, T. 13, R. 20.

The three wells in this section are the property of Mr. W. T. Clark. Nos. 2 and 3 were put down in 1892 and No. 17 was drilled in 1899. No. 2 is the smaller of the two wells near Mr. Clark's house, being 4–$3\frac{1}{2}$ inches in diameter, with a discharge probably less than half that of No. 3, which is 5 inches in diameter at the top. Wells Nos. 2 and 3 have practically the same elevation and are so close together as to have the same log. Mr. Clark reported the pressure from them in 1897, as determined by a gage test, to be 50 pounds. The cost of these two wells was more than $2,500. They are the oldest wells that are flowing to-day. Well No. 17 is a short distance to the northeast of the other wells, near the center of the section. It is not so deep, and its water is 3 degrees cooler. These three wells are only partially cased, which is believed to account for a decrease in discharge since they were put down.

WELLS IN SEC. 32, T. 13, R. 20.

Well No. 13 is in the northwest quarter of the southeast quarter, on the ranch owned by I. Desmarais. It was drilled by Mr. Buwalda, being completed in March, 1899, when the discharge measured 0.8 second-foot. It is cased to a depth of 428 feet, cutting off the first flow. The pressure at this well was low from the time of its completion, and in June, 1900, it ceased to overflow. The water stands 6 feet below the surface, and is conducted above ground by a short trench. A pump is used a portion of the time to irrigate higher parts of the ranch.

A well was drilled in this section, by Mr. W. T. Meigs, to a depth of

GANO WELL, MOXEE VALLEY.

623 feet, and a small flow of water was found, but the well is now dry.

MISCELLANEOUS WELLS.

The Yakima Land Company were the pioneers in putting down wells in Moxee Valley, well No. 1, section 3, being drilled in 1891. Three other wells were drilled by this company, in sections 3, 4, and 14, but not one of them is flowing at the present time.

In section 12, of the next township west, a well was drilled to a depth of 707 feet, and when the work was abandoned water stood at 70 feet from the surface.

Well No. 24 is near the southwest corner of the southeast quarter of sec. 29, T. 13, R. 18, on the ranch of George Wilson. It was completed in August, 1899, and cost $2,500. The expense of this pioneer well in Wide Hollow was met by a small company of ranch owners, the agreement being that in the event of the well proving successful all of the shares should be bought by Mr. Wilson. Thus the owner of the well was not obliged to assume the entire expense of what might have been a fruitless prospect for artesian water, while, on the other hand, the property owners, who shared the risk, now possess, at no expense to themselves, the important information of the presence of artesian water. The well is very successful, is of fairly good size, and is well cased, the diameter of the casing being from 5⅛ inches to 3½ inches. When completed it had a pressure sufficient to force a strong stream through the drill rods to a height of 42 feet above the surface, equivalent to 1,207 feet above sea level. The drilling was extended until basalt was struck, about 200 feet below the lowest flow and about 100 feet below sea level. The well has shown no variation in volume.

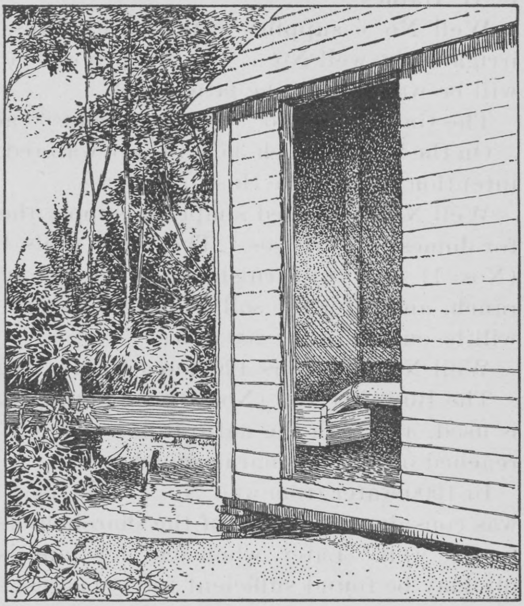


FIG. 8.—Wilson well, Wide Hollow.

AREA WATERED.

In the season of 1897 well No. 1 furnished water for the irrigation of 250 acres, and in 1900 it supplied eight small ranches with water, the total area irrigated being 297 acres. This is plainly more than can satisfactorily be watered by this well, and the completion of well No. 23 will render unnecessary the use of water from the Clark well to serve the Peck ranch.

Wells Nos. 2 and 3 are reported to have irrigated 120 acres in 1897. In the summer of 1900 the flow from No. 2 was used on a market garden of 20 acres, while Nos. 3 and 17 were used to irrigate 90 acres of orchard, alfalfa, and other crops. Ninety acres of winter wheat were also irrigated on this ranch.

Wells Nos. 4 and 22, on Mr. Longevin's ranch, water 80 acres.

Well No. 5 is used for the irrigation of 85 acres on the ranch of Mr. C. H. Haines.

Well No. 6 supplies water for 40 acres, which is also the amount irrigated by well No. 7, but it is probable that in the future more land will be watered by the latter well.

The Gano well, No. 8, waters about 60 acres.

On the Sauve ranch 35 acres are watered by well No. 9, and it is the intention to increase this to 40 acres.

Well No. 10 is used simply to supply the Holland ranch with water for domestic purposes. The other wells belonging to this company (Nos. 11 and 16) furnish water for 115 acres of alfalfa on the same ranch, and after the soil is once thoroughly wet the supply probably will be sufficient for 200 acres.

Well No. 12 waters 120 acres on Mr. Regimbal's ranch.

The Buwalda well (No. 13) can supply water for 50 acres if a pump is used, and with the natural flow through the trench 25 acres can be reached on the Desmarais ranch.

In 1900 water from well No. 15 was used to irrigate 100 acres, which was considered by some of the shareholders to be too great an acreage for the well. Later, when less new land is under irrigation, the supply may be found sufficient for 100 acres, if not more.

Well No. 18 is believed by Mr. Allwardt to have a discharge sufficient for the irrigation of 100 acres.

The Deeringhoff well (No. 19) watered 42 acres the first year, and is expected to supply 60 acres later. The other well on the same section (No. 21) has only a small flow, which is used on about 3 acres.

Well No. 23, just completed, is reported to have a flow equal to that of No. 1, and it will therefore be an important addition. In 1900 Mr. Peck had 114 acres under irrigation from well No. 1, which will probably now be supplied from his own well. The shade trees planted on this ranch, as well as a proposed pond near the house, promise to make the place very attractive. Where attention has been given to the use of artesian water around the residences as well as in the fields and orchards, the returns have been very gratifying, and the contrast between such ranches and the surrounding sagebrush areas is great.

It is estimated that the score or more of wells now flowing in Moxee

Valley have an aggregate discharge sufficient to irrigate about 1,600 acres. Doubtless less wasteful methods of irrigation would enable a still greater acreage to be cultivated in this arid valley without any increase in the flow of the wells.

Well No. 24, on the Wilson ranch, in Wide Hollow, has a discharge sufficient for the irrigation of 50 acres. The water is used, with that from a ditch, to irrigate 80 acres, but the well is reported to have done most of the work after July 1, the flow in the ditch being very small.

SOURCE OF THE ARTESIAN WATER.

The discussion of the source of the artesian water becomes of interest, since it may throw light upon the permanence of the supply. The underground waters of an arid region, like the surface waters, are not indigenous, but come from a distance. Commonly their source is found along the edges of the artesian basin, which may be hundreds of miles distant. There, the outcrop of the water-carrying beds forms a catchment area where the surface waters enter the underground circulation.

PRECIPITATION.

Since the Atanum-Moxee Basin is comparatively limited in extent, it follows that it must in great part fall within the region characterized by an arid climate. Especially is this true of the eastern part of the basin, where the lower beds of the Ellensburg formation outcrop along the ridges which border Moxee Valley. There the rainfall is very scanty, the annual precipitation being even less than that given on page 13. Much of the rain comes in the form of heavy showers or cloud-bursts, which find the baked soil wholly unfitted to receive the moisture, so that the proportion of run-off is at its maximum. The contribution to the artesian basin in this portion of the catchment area, therefore, is small, and were it the only supply the artesian wells of Moxee Valley could not be expected to maintain their flow for any length of time.

At the western end of the basin the conditions are somewhat more promising. The Ellensburg sandstones extend up on the flanks of the higher ridges, which are favored with greater precipitation, as is shown by the groves of large pine trees which cover them. There the snowfall is much heavier, and as the winter's accumulation melts the conditions are much more favorable for the reception of the water by the soil. Exact figures can not be obtained upon which to base even an approximate estimate of the water delivered in this way to the artesian basin. The occurrence of surface springs along these ridges shows that even the supply of ground water is sufficient to persist through the summer. It is probable that the immediate loss by run-off is not excessive in this part of the catchment area, so that the contribution to the underground supply is an important one.

STREAM CONTRIBUTION.

Another source for the underground waters may be found in the leakage from streams crossing the outcrop of the water-carrying beds. Several seasonal streams flow down the sides of the western part of the Atanum-Moxee Valley, but these are small, and their contribution may well be included under that mentioned in the preceding paragraph. Atanum Creek, however, drains a large area to the west, and in the early part of the year it is an important stream. It enters the synclinal basin at a point where the strata have gentle dips and where the sandstone at the base of the Ellensburg is open and porous. At the points where the stream crosses these upturned beds the water might seep downward into the artesian basin. Similar seepage is shown where ditches have been dug in both the surficial alluvium and in the Ellensburg sandstone. The green vegetation along the lower sides of such ditches testifies to the presence of water which has escaped through the soil and the sandstone. The fact of the seepage from Atanum Creek, however, is conclusively proved by other evidence. The stream measurements made by Mr. Babb, and quoted on page 33 of this report, have an important bearing on this question when studied in connection with the geologic relations along Atanum Creek. As will be seen by reference to the geologic map, Pl. II, the two forks of Atanum Creek enter the sandstone area above Tampico, but the stream again encounters the basalt below that place. The first measurement of the north fork of the creek was made above the point where the stream crosses the base of the sandstone, and this volume is seen to exceed, by 10 second-feet, the total volume of both forks measured below their junction and within the sandstone area. The loss by seepage is partly returned when the stream again flows upon the basalt basement, as is shown by measurement No. 9 of the table on page 33. This gain doubtless represents the return of a part of the underflow of the stream to the surface. Additional measurements farther down show a loss of 3.8 second-feet after the sandstone again becomes the floor of the valley. Further loss is shown by measurements made along the lower course of the creek, but those mentioned are of importance as showing seepage into the sandstone.

This contribution of several second-feet of water is an important one, and since these measurements were made late in July they represent a minimum of flow and probably also of seepage. At time of flood the amount flowing into the artesian basin from this source would be even greater. Taking into account the aggregate discharge of the wells of the basin, which is about 12 second-feet, the part played by seepage can at once be seen.

LEAKAGE FROM A LOWER BASIN.

In his reconnaissance of this area Professor Russell noted the scanty rainfall and concluded that the annual precipitation on the outcrops of the water-bearing beds on the ridges adjacent to Moxee Valley was wholly inadequate to supply the wells.[1] The extension of the Ellensburg formation westward as far as shown on the map, Pl. II, was not then known, and this addition to the catchment area was therefore not taken into account. This supposed absence of any adequate surface supply and the high temperature of the artesian water were cited in support of the hypothesis that the Moxee artesian basin "is supplied from below by water rising through fissures or from the leakage upward of a lower artesian basin."[2] Further support of this hypothesis was believed by Professor Russell to be found in a fault possibly extending across the Atanum-Moxee Valley from Selah Gap to Union Gap. The evidence of fissure springs along a fault scarp in Selah Valley was also cited.

In the consideration of this hypothesis it may be well to note that further study of this area fails to show any north-south fault across the basin. As previously stated, this region is one of regular folds, with no important faults. The springs in Selah Valley near the old Ellensburg road may be termed fissure springs, but the cracks through which the water reaches the surface probably do not extend to any great depth, as the water is not warm, but is cold and very palatable. This is quite generally true of the water of springs along the lower slopes of the basalt ridges. The Clerf Spring, east of Ellensburg, described on page 45, is perhaps the most important fissure spring known in the Yakima Basin, and should be considered in this connection. Here is a large flow upward through fissures in the basalt, but the temperature of the water is considerably less than that of the artesian water in Moxee Valley. This spring proves the presence of water in the basalt at this point, and a similar source is possible for the artesian water of the Moxee wells. Evidence bearing upon this hypothesis must be indirect, however, since there are no traces of any fissures in the Moxee Basin extending upward from the basalt into the Ellensburg formation. Faulting of the nature to produce such fissures has not been detected in the basin.

The possibility of a lower artesian basin deserves a word in connection with this discussion. The Eocene sandstones which underlie the Yakima basalt farther west are of a nature to be good water carriers. They outcrop in elevated portions of the Cascade Range, where the annual precipitation is considerable, and may extend downward beneath the basalt of the North Yakima region. In that event they would contain large quantities of artesian water. The depth at which these sandstones are buried beneath the basalt, however, is such as utterly to preclude drilling wells to tap their supply of water. Furthermore, the folding to which these rocks were subjected before the basalt covered them makes the existence of a true artesian basin beneath the basalt quite problematical. Thus it is again found impos-

[1] Bull. U. S. Geol. Survey No. 108, p. 58.

[2] Op. cit., p. 59.

sible to test direct the hypothesis of leakage upward from a lower basin. The facts which would bear upon this are beyond the zone in which geologic observation is possible.

TEMPERATURE DATA.

The temperature of the artesian water varies considerably in the different wells of the basin. As will be seen in the table on page 49, the range in temperatures is about 14 degrees. Doubtless there are several factors that enter into this variation. Among those which directly affect the temperature of the artesian water freely flowing from a well, the principal one is the depth of its source. The excess of the water's temperature above the mean annual atmospheric temperature, which is approximately 50 degrees in Moxee Valley, is generally considered more or less directly proportionate to the depth of the water horizon. Unfortunately, in the present case, the problem is not simple, since most of the wells are supplied with water from flows at several horizons. In such wells the discharge is mixed water from the several depths, and its temperature is consequently a resultant of the mixture.

Three of the wells tap the upper flow only, and these furnish data from which the rate of increase in temperature can be calculated. In three other wells (19, 18, and 22 of the following table) the upper flows are cased off and the lowest flow only is used. The following table shows the gradient or rate of increase for these wells, expressed in feet for 1 degree:

Table showing relation of temperature to depth in wells in Atanum-Moxee Basin.

No. of well.	Depth of flow.	Temperature.	Gradient.
	Feet.	*Deg. F.*	*Feet.*
7	515	70.7	24.8
4	637	72.2	28.7
10	835	73.2	36.0
19	625	73.2	26.9
18	752	72.2	33.8
22	820	72.7	36.1

It is at once noticed that these wells have abnormally warm water, a fact which is brought out by the rates of increase or gradients shown in the table. In other regions the usual rate of increase is 1 degree in 50 feet, so that the normal temperature for water from a depth of 500 feet in a region where the mean annual temperature is 50 degrees would be 60 degrees. It will be seen that all of the Moxee wells show a much higher rate of increase. For example: Well No. 7 has water about 10 degrees warmer than would be expected, considering the depth, which is only 515 feet. In the second place, it will be noted that the thermometric gradient is steeper in the shallow wells.

Before attempting to account for the abnormal temperature of the water, or to explain the rather exceptional variation in gradients, attention should be given to several factors which might be thought to influence the recorded temperatures. Observations of well temperatures are usually scattered over large areas, so that some differences are to be expected, but in the present case the area in which these six wells are located is limited, being not more than $1\frac{1}{2}$ miles in longest diameter. Neither is the difference in elevation great, being only about 120 feet, and if the position of the water horizons be expressed in elevations above sea level the variation in gradient is not materially affected. Again, while overflowing wells undoubtedly afford the best measure of underground temperatures, it may be thought that there is considerable loss of heat in the passage of the water to the surface, so that the deeper wells might show a lower thermometric gradient. The wells here considered were all flowing freely at the time of observation, with the exception of No. 10, which, however, shows a gradient slightly steeper than No. 22, which is not quite so deep. This factor of loss of heat in the passage of the water upward in the well tube can therefore apparently be disregarded. If it were at all important, it would show underground water temperatures even more abnormal than is expressed in the foregoing table.

Temperature data obtained in artesian wells may be assumed to indicate underground temperatures, and the records from wells in different countries have been used generally by geologists and physicists in determining the normal rate of increase of temperature as the earth's crust is penetrated. It does not seem plain, however, that the water temperatures given in the foregoing table necessarily represent the earth temperatures at the levels where the wells tap the water-bearing beds. The water from these wells possesses a relatively high temperature, which may be regarded as having its origin not in the immediate source but in the greater depth from which the water is derived. The high temperature, therefore, may be said not to be indigenous but transferred. This theory involves considerable movement of the underground water, in order that the progress upward may be rapid enough to prevent loss of heat to an extent sufficient to bring the temperature of the water down to the normal temperature for the depth at which the flow is encountered. This upward transfer of heated waters must of course cause a temperature change in the inclosing rock, except where this is impervious, and therefore possesses a relatively low degree of conductivity.

This hypothesis not only accounts for the high temperature, but may also serve to explain the variation in gradient. In their progress upward (a movement taking place for the most part along the beds, and thus involving a horizontal element much greater than the vertical) the waters lose a portion of their heat, as is shown by the fact that in most cases the deeper wells discharge the warmer water.

According to the foregoing table, this loss of heat varies from 1 degree in about 100 feet to only one-half degree in 173 feet, and being entirely out of proportion with the usual rate of decrease in earth temperatures, it follows that the wells which tap the flow near the surface, and relatively higher, must show a steeper thermometric gradient than the deeper wells.

Since the lateral element is so important in the underground movement of artesian water, attention must be given to the relative position of the wells, especially with regard to the form of the basin and its probable influence upon the waters moving within the beds of sandstone. Wells Nos. 18 and 19 furnish an exception to the statement that the deeper wells discharge the warmer water. In this case, well No. 18, although tapping the water horizon 127 feet deeper beneath the surface than well No. 19, or about 100 feet lower referred to sea level, discharges water 1 degree colder than the latter well. An explanation of this may be found in the structure of the basin. As shown in fig. 7, page 48, the syncline is sharply compressed on the south side, and, as has already been stated, it is probable that the sandstones may have had their texture affected by this compression, especially their porosity. Well No. 18 is near the south side of the basin, and thus possibly within the area affected. On this supposition there is a less free movement of the underground waters in their flow toward this part of the basin, and therefore they suffer a greater loss of original heat. This hypothesis is supported by the fact that wells Nos. 5 and 9, in this part of the area, while supplied by several flows, and therefore not available for direct comparison, show the lowest gradients of any wells in the district; that is to say, they discharge cooler waters compared with wells not so deep and situated a mile or more farther north in the same basin. The comparison of these wells, supplied with what may be termed mixed waters, is not tabulated, for the element of depth becomes too complicated, owing to the several flows contributing to the discharge. It may be stated, however, that here also the general rule is that the shallower the well the steeper the gradient or rate of increase of temperature.

This discussion of the temperature data has its practical bearing on the subject of the direction of movement of the underground water and the origin of the supply. Regarding direction of flow, the evidence points to a movement along the trough of the syncline from the west, and since the dip or pitch of the fold is here to the west the movement is upward. The source of this water, then, is west of the well district in Moxee Valley. This accords with the statements made on page 13, regarding the greater precipitation in the western part of the region. Again, if the fissure hypothesis is assumed to be correct, the probable position of the fissures, as stated by Professor Russell, is in the vicinity of Yakima River, or west of these wells.

The abnormally high temperature of the water in all of these wells, together with the variation in gradient, is therefore assumed to indicate upward movement; and the question remains, What is the depth at which the original temperature is acquired? It is possible that the lowest point in the syncline is deep enough to give temperatures similar to those recorded, even with a more nearly normal gradient. This, however, would not allow for any loss of heat as the water moved upward along the bottom of the basin. Furthermore, the temperature of the water from the Wilson well, in the western part of the basin, is 80 degrees, which would indicate a gradient of 1 degree in 35 feet, provided the discharge was all from the lowest flow; but being from three flows, the true gradient is somewhat steeper. This well being west of the lowest part of the basin and nearer the surface intake previously suggested, its waters are not heated by having reached any lower depth, unless fissures supply the basin. The whole question thus resolves itself into an inquiry whether the excess of temperature is due to the artesian water having its origin in fissures extending down into the basalt basement, or to a general and regional high temperature for the whole floor of the basin.

The thickness of the Yakima basalt under the Atanum-Moxee Basin is not less than 2,500 feet, and is probably much greater. So far as known, this formation includes no porous beds extensive enough to form a water horizon. Fissures extending through this mass of rock to any water-bearing beds beneath would be supplied with water of a much higher temperature than any found in these wells. Even with excessive loss of heat, the water from such a source would be hot rather than warm. The alternative hypothesis of a regional high temperature appears more plausible. This great thickness of basalt which underlies the sandstone was poured forth in Miocene time, or comparatively late, as floods of molten rock. While in the millions of years since its eruption it doubtless has lost practically all of its original heat, yet it seems probable that the cooling of the earth's crust must have been retarded over the large areas covered by these great Miocene basalt flows, especially in view of later volcanic activity, as evidenced by the Pleistocene andesitic eruption. This would result in higher earth temperatures in this region, so that the normal gradients could not be expected. Thus, since the Wilson well discharges water from three flows, the lowest of which is at a depth of 1,050 feet, the true gradient must be steeper than 1 degree increase in 35 feet.

In his study of the Dakota artesian basin, Mr. N. H. Darton[1] discovered rather exceptional thermal conditions for which no satisfactory explanation has been found. The occurrence of steep thermometric gradients over large areas may indicate here also a conservation of earth heat through the thick mantle of Mesozoic strata. Near Boise, Idaho, the conditions are more like those of the Yakima region. There the Payette sandstone is of the same age as the Ellensburg formation and, like it, contains the water-bearing beds. Hot springs issue from that sandstone, and wells sunk near the city found, at a

[1] Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. IV.

depth of about 400 feet, a supply of artesian water which has a temperature of 170 degrees. As shown by Mr. Waldemar Lindgren,[1] this hot water is apparently derived from the vicinity of volcanic vents, where in Pliocene time basaltic lava broke through the Payette sandstone.

PERMANENCE OF SUPPLY.

The practical question which comes both to those who have wells and those who are considering the advisability of drilling for water relates to the permanence of the artesian supply. The preceding section may have answered this question in part, but a few additional observations may pertinently be made.

DECREASE OF PRESSURE.

The perceptible decrease in the pressure of some of the older wells has been thought by some residents of the district to indicate an early failure of all of the wells. In most cases it will be noted that the wells first put down were located on higher ground than most of the wells at present flowing. In many of these early wells the original pressure was low, so that even a slight reduction changed them from flowing to nonflowing wells.

Several features may be cited as contributing to this decrease in pressure. When the first wells were put down the water in this basin undoubtedly was under considerable pressure, which would naturally be lessened as the stored supply of water was drawn upon. Few of the earlier wells were cased, and the possibility exists that caving and partial clogging of the wells have caused the lowering of the pressure. Lack of casing has also doubtless contributed to leakage at horizons where a difference in pressures allowed the water to escape. With even the best well construction the decrease in pressure would continue until the total discharge of the wells of the area equaled the amount of water received by the basin. The indications, judging from the testimony of the well owners, are that this state of equilibrium has been reached.

INCREASE IN NUMBER OF WELLS.

Each year new wells are being drilled in Moxee Valley, and it is probable that the success of the Wilson well will cause other wells to be put down in Wide Hollow, where water is needed. In the Moxee area, it is doubtful whether, under present conditions, the increase of wells will result in any increase in the total discharge, if the supposition be correct that the discharge now equals the supply. New wells will mean, therefore, only a further division of the water supply. In certain cases this will be advantageous, if it enables the water for irrigation to be distributed more economically. But as further demands are made upon the underground supply of water, the time must come when it will be a survival of the fittest, since the lowest

[1] Geologic Atlas U. S., folio 45, Boise, Idaho.

wells, especially those which are situated where the underground movement of water is least restricted, will continue to flow even after the pressure is lowered to a point where the higher wells can not be supplied. If the foregoing suppositions regarding the movement of the artesian water in this basin are correct, the wells that would continue to flow would be those having the warmest water.

The underground supply of water must not be considered unlimited, any more than the surface supply. The artesian basin should be regarded simply as a reservoir in which water is collected and stored, and not only should wasteful use of it be avoided, but the fact that it is stored should rather prompt economy in its use. In view of the possibility of exhausting the artesian resources of the district, more attention should be given to preventing waste of the water.

PRECAUTIONS TO BE OBSERVED.

Unfortunately, some wells are so constructed that the discharge can not be controlled, and waste must continue both at the surface and below; hence it is of prime importance that attention be given to correct construction of the wells. The following practical hints, quoted from a report of Prof. J. E. Todd,[1] will serve to call attention to geologic conditions which must be kept in mind if a well is to be a permanent success:

> (1) Since the pressure in the upper flows is less than in the lower by many pounds to the inch, it is very important that the communication between the lower flows and the higher should be entirely cut off, otherwise the full pressure from the lower stratum will not be observed at the mouth of the well, but will expend itself by leaking into the strata below the surface. The desire of the well digger to keep his pipe loose may tempt him to leave the bore too large—hence the danger we speak of.
>
> (2) It is very desirable that the larger pipe lining the bore be firmly fixed in the hard stratum above the water-bearing rock. This may be done in most localities, as a compact stone is found just above the porous sands which bring the water. Much depends upon this, for if a pipe be left loose and the opening in the rock left incompletely stopped water is likely to escape around the pipe, and if not checked may eventually destroy the well.
>
> (3) A well should be sunk as rapidly as consistent with good work, especially after water has been reached, otherwise the great pressure of the water may cause it to erode an irregular opening and prevent the accomplishment of the two points already given.

The leakage from lower flows into upper porous beds apparently has taken place in Moxee Valley. A spring which within a few years has broken out near the center of sec. 9, T. 12, R. 20, very probably is supplied by leakage from some of the wells in sections 10 or 3 which have stopped flowing. This loss may be sufficient to make a well valueless, and it is an argument for properly casing a well, an additional expense at the time, but an outlay that will insure the whole investment.

Most important of all is the economical use of water. In 1900 few

[1] Water-Supply and Irrigation Paper U. S. Geol. Survey No. 34, p. 30.

wells in the Moxee district were supplied with valves, and therefore the full discharge continues day and night, summer and winter, regardless of whether or not the water is needed. This flow of the wells in the winter is a wholly unnecessary drain upon the underground supply, and is doubly to be deprecated since the presence of the water on the land during that season of the year must be injurious. Entirely shutting off the discharge might introduce the danger of clogging the wells with sand, but they could be fitted with valves so that most of the water could be shut off. In addition to shutting off the supply, the valve can, by partial closing, be used to increase the pressure and thus force water through a smaller pipe into the house.

Closing the wells during the winter months, except for very small flows sufficient for ordinary use about the house and for the stock, would result in the accumulation of water, which would be available the following summer, when most needed, and the pressure for the whole basin would undoubtedly be increased, as shown by a fact cited by Mr. Frank Leverett.[1] Wells in the vicinity of the Chicago stock yards are reported to flow for only a brief period each week, after the Sunday intermission from pumping. In that case a few hours' accumulation proves sufficient to raise the pressure, and it is plain that several months' accumulation would make considerable difference in the pressure in the Moxee wells.

This matter of economy in the use of the artesian water should be taken up by those most interested. Legal enactment would not accomplish much more than a local agreement. The result desired is to insure a permanent supply of water for the irrigation of the valley, and every property owner in the district should be ready to subscribe to articles of agreement. This arrangement appears practicable, since those interested live within a radius of a few miles and constitute practically a single community.[2]

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[1] Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. II, p. 787.

[2] Since the completion of this manuscript it has been learned that the conservation of the underground water supply of the Moxee Basin has been provided for by legislative enactment, and that the following bill is now on the statute books of the State of Washington. Such a law as this is unique in its form and application. It undoubtedly meets with the hearty approval of those most interested, and should be rigidly enforced.

CHAPTER CXXI.

(H. B. No. 203.)

RELATING TO ARTESIAN WELLS.

AN ACT in relation to artesian wells and regulating the flow of water therefrom, and providing a penalty for the violation thereof.

Be it enacted by the legislature of the State of Washington:

SECTION 1. It shall be unlawful for any person, firm, corporation, or company having possession or control of any artesian wells within the State, whether as contractor, owner, lessee, agent, or manager, to allow or permit water to flow or escape from such well between the first day of October in any year and the first day of April next ensuing: *Provided*, That this act shall only apply to sections and communities wherein the use of water for the purpose of irrigation is unnecessary or customary, and providing further, that nothing herein contained shall prevent or prohibit the use of water from any such well between said first day of October and the

The future of Yakima County promises to be such that every foot of water available for irrigation can and will be utilized. A few hours' ride over any part of the county where new land is being put under cultivation is sufficient to convince one of the great agricultural possibilities of the region, but without proper conservation of the water resources these possibilities can not be made to contribute to its future wealth.

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first day of April next ensuing for household, stock, and domestic purposes only, water for said last-named purposes to be taken from such wells through a one-half inch stop and waste cock to be inserted in the piping of such well for that purpose.

SEC. 2. It shall be the duty of every person, firm, corporation, or company having possession or control of any artesian well, as provided in section 1 of this act, to securely cap the same over on or before the first day of October in each and every year in such manner as to prevent the flow or escape of water therefrom, and to keep the same securely capped and prevent the flow or escape of water therefrom until the first day of April next ensuing: *Provided, however*, it shall and may be lawful for any such person, firm, corporation, or company to insert a one-half inch stop and waste cock in the piping of such well, and to take and use water therefrom through such stop and waste cock at any time for household, stock, or domestic purposes, but not otherwise.

SEC. 3. Any person, whether as owner, lessee, agent, or manager, having possession or control of any such well, violating the provisions of this act shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be fined in any sum not exceeding two hundred dollars for each and every such offense, and the further sum of two hundred dollars for each ten days during which such violation shall continue.

SEC. 4. Whenever any person, firm, corporation, or company in possession or control of an artesian well shall fail to comply with the provisions of this act, any person, firm, corporation, or company lawfully in the possession of land situate adjacent to or in the vicinity or neighborhood of such well and within five miles thereof may enter upon the land upon which such well is situate, and take possession of such well from which water is allowed to flow or escape in violation of the provisions of section 1 of this act, and cap such well and shut in and secure the flow or escape of water therefrom, and the necessary expenses incurred in so doing shall constitute a lien upon said well, and a sufficient quantity of land surrounding the same for the convenient use and operation thereof, which lien may be foreclosed in a civil action in any court of competent jurisdiction, and the court in any such case shall allow the plaintiff a reason able attorney's fee to be taxed as a part of the cost. This shall be in addition to the penalty provided for in section 3 of this act.

Passed the House March 7, 1901.

Passed the Senate March 14, 1901.

Approved by the Governor March 16, 1901.

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